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AN ECOLOGICAL INVESTIGATION OF A VANADIUM AND URANIUM MILL TAILINGS SITE

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May 1996

Prepared for
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Health and Safety Research Division
Environmental Technology Section
Oak Ridge National Laboratory
Grand Junction, Colorado

Prepared by the
Environmental Sciences Division
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LOCKHEED MARTIN ENERGY RESEARCH CORP.
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1. INTRODUCTION

From 1942 through 1946, the Vanadium Corporation of America operated a vanadium and uranium mill in Monticello, Utah (Rust Geotech 1995a). In 1948, the U. S. Atomic Energy Commission (AEC) purchased the mill site and milled uranium from 1949 until the mill was permanently closed in January 1960. During operation of the mill, associated contaminants were released into the surrounding environment through atmospheric releases, effluent discharges into Montezuma Creek which flows through the middle of the mill site, and runoff and soil infiltration from associated tailing piles. In 1961, the AEC stabilized the tailing piles by covering them with soil, and by 1975 the mill structure had been demolished and buried (Rust Geotech 1995a; Rust Geotech 1995b). These actions however, did not eliminate surface water or ground water contamination. In 1989, the mill site was placed on the Comprehensive Environmental Response, Compensation, and Liability Act's National Priorities List. Remediation of portions of the properties was initiated in approximately 1992 and completion is anticipated in the late 1990's.

Elevated concentrations of several contaminants have been found in the surface water of Montezuma Creek and in ground water on and near the mill site (Crist and Trinca 1988; Rust Geotech 1995a). Arsenic, iron, manganese, molybdenum, selenium, uranium, vanadium, and zinc are at least periodically elevated downstream of the mill site, and activities of gross alpha, gross beta, and radium-226+228 are above background. Additionally, high concentrations of total dissolved solids, sulfate, phosphate, and nitrate+nitrite typically occur, specific conductance and alkalinity are elevated, and pH has exceeded 9.0 on a few occasions.

The objectives of this study were to provide the data needed to (1) assess the ecological risk of biota in Montezuma Creek to contaminants associated with the mill site, and (2) evaluate and document the current ecological condition of Montezuma Creek so that the effectiveness of future remedial actions can be evaluated.

2. STUDY AREA

The Monticello Mill Tailings Site is located in southeast Utah in San Juan County. The mill site is bisected by Montezuma Creek which originates from several small tributaries that drain the Abajo Mountains just west of Monticello. The stream flows east through Monticello and the middle of the mill site, enters Montezuma Canyon, and then flows south about 90 km to its confluence with the San Juan River about 24 km east of Bluff, Utah. The majority of the study focused on a 6.7 km reach of Montezuma Creek from about 1.0 km upstream and west of the mill site to just downstream of Vega Creek, a tributary located approximately 6 km downstream of the mill site (Fig. 2.1). Eight sites within this area, an additional site downstream of the confluence of Montezuma Creek and Verdure Creek, and a reference site on Verdure Creek were sampled for one or more of six tasks (Fig. 2.1; Table 2.1). The selection of sample sites was based on previous sediment and soils data (Rust Geotech 1995a) that indicated possible areas of high contaminant concentrations and appropriate habitat requirements within the stream channel for the benthic macroinvertebrate and fish communities.

Within the study area, Montezuma Creek is a third-order, perennial stream of approximately 2.2 m mean width and 19 cm mean depth (Table 2.2). Watershed areas for the sample sites range from 57 to 248 km^2. Stream flow is greatest during spring and early summer with base-flow to no-flow conditions in late summer and fall (Rust Geotech 1995a). An upstream reservoir (Lloyds Lake), constructed in 1985, has stabilized base-flows and reduced the number of no-flow days (Crist and Trinca 1988; Rust Geotech 1995a). Based on U. S. Geological Survey (USGS) data from a gauging station located just upstream of Hwy. 191 (Table 2.3), the number of zero-flow days has been highly variable, but generally less than 10% of the year from 1988-1992. Elevation of the sample sites ranges from 2109 m at the Monticello golf course (i.e., site MZG) to 1719 m at the site just downstream of the confluence of Montezuma Creek and Verdure Creek. The gradient progresses from moderate (10.8 m/km) at the location above the mill site to very high (53.0 m/km)

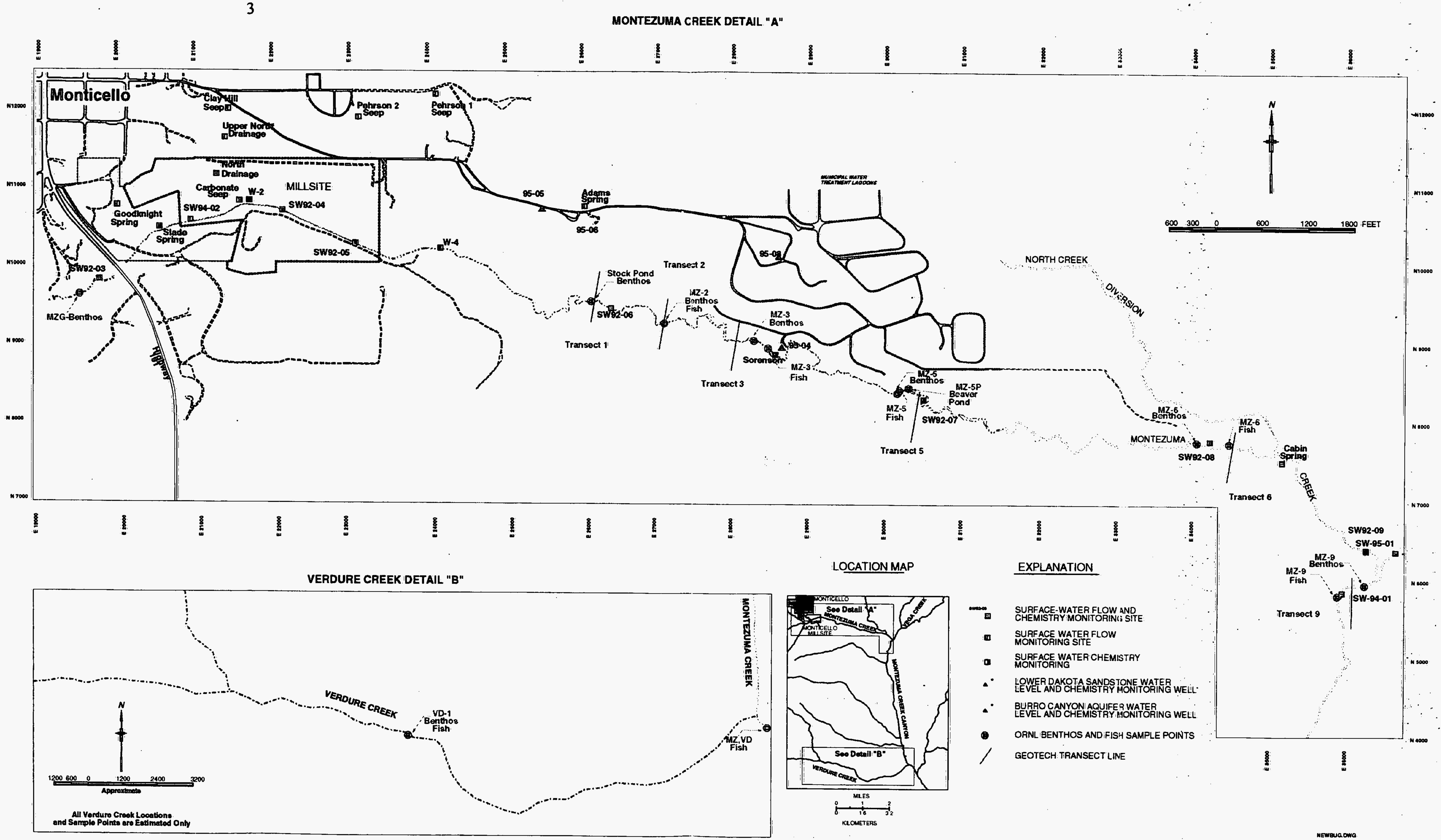


Fig. 2.1. Montezuma and Verdure Creek Macroinvertebrate and Fish Sample Locations

Table 2.1. Sample activities at sites in Montezuma Creek and Verdure Creek .

	Sites[a]									
Task	MZG	SP	MZ-2	MZ-3	MZ-5	MZ-5P	MZ-6	MZ-9	VD-1	MZVD
Benthic macroinvertebrate community - qualitative		X				X				
Benthic macroinvertebrate community - quantitative	X		X	X	X		X	X	X	
Benthic macroinvertebrate bioaccumulation			X	X	X			X	X	
Fish community - qualitative						X	X	X		X
Fish community - quantitative			X	X	X			X	X	
QHEI habitat analysis			X	X	X			X	X	

[a]Montezuma Creek transects = MZ-x, Stock Pond = SP, Beaver Pond below MZ-5 = MZ-5P, Verdure Creek =VD, Montezuma Creek at Golf Course = MZG, and Montezuma Creek below Verdure Creek = MZVD.

Table 2.2. Site characteristics for fish sampling reaches in Montezuma Creek and Verdure Creek.

	Sites						
Parameters	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZVD
Surface area (m^2)	244	213	154	363	284	295	191[a]
Watershed area (km^2)	66	67	69	99	248	45	524
Elevation (m)	2052	2042	2038	2005	1995	1999	1719
Gradient, m/km (ft/mile)	14.8 (78.2)	21.1 (111.2)	25.0 (132.0)	23.0 (121.4)	53.0 (279.8)	16.7 (88.0)	6.0 (31.7)
Pool:riffle ratio	1.33	2.03	1.19	0.74	1.45	2.22	NM[b]
Mean width (m)	2.86	2.15	2.17	1.88	2.09	1.81	NM
Mean depth (cm)	15.9	17.6	22.1	25.5	15.6	11.3	NM

[a]Length of stream sampled.
[b]NM = Not measured.

Table 2.3. Flow data (discharge, cubic feet per second) recorded at USGS gage at Monticello Golf Course, 1980-1992.

Water year	Mean daily flow (ADF), annual	Mean daily flow for Aug 1- Sep 15 (CPF)[a]	CPF/ADF (%)[a]	Number days of zero flow
1980	12.80	0.02	0.2	223
1981	0.16	0.19	115.6	199
1982	0.34	0.11	30.9	103
1983	19.50	0.20	1.0	0
1984	1.93	0.11	5.6	0
1985	5.89	0.06	0.9	0
1986	0.69	1.02	148.0	0
1987	2.02	0.19	9.2	0
1988	1.48	0.81	54.4	0
1989	0.70	0.42	59.7	95
1990	0.11	0.11	98.8	2
1991	0.09	0.02	17.0	36
1992	0.29	0.09	31.6	17
Means 1980-92	3.54±5.97	0.26±0.31	44.1±48.9	52±79
Means 1988-92	0.53±0.58	0.29±0.33	52.3±31.2	30±39

[a]CPF = Average daily flow during August and first half of September only, from gauging station records, based on methodology of Binns and Eiserman (1979).

at site MZ-9 within Montezuma Canyon. In the portions of the creek between the mill site boundary and Montezuma Canyon, beaver dams are prominent with many resulting ponds. The beaver pond at site MZ-5P was approximately 30 to 50 m wide and more than 1 m deep. In the lower sections closer to Montezuma Canyon, beaver activity is less pronounced and pools are a result of natural hydrological features with moderate width (<5 m) and depth (<1 m). Riparian zones along the creek include agricultural pastures, sagebrush, grasses, and willow. Oak-juniper communities dominate the canyon walls (Rust Geotech 1995b). Most sample sites lacked high canopy shading, with grasses, sedges, and shrubs providing minimal, low level shade. The substrate is primarily composed of a mixture of gravel and cobble, but increased amounts of boulders occur with downstream distance. Within the beaver ponds, extensive deposition of fine sediments has occurred. At the time of sampling (August 1995) instream vegetation and periphyton (primarily filamentous green algae) was well developed in most sections, probably aided in part by the lack of shading.

The reference stream, Verdure Creek is located due south of the study stream (Fig. 2.1) and is similar to Montezuma Creek in watershed area, gradient, and elevation (Table 2.2). Verdure Creek at the sample site location did not have beaver activity, and the riparian zone included greater proportions of natural communities of willows, sedges, and sagebrush with oak-juniper on canyon slopes. Instream vegetation at the time of sampling included thick mats of green filamentous algae and some cattails. A major difference between Verdure Creek and Montezuma Creek watersheds was land use. Urban development from the city of Monticello, a community golf course, crop land, and livestock grazing were in the Montezuma Creek watershed. Land use in the Verdure Creek watershed included livestock grazing and cropland.

Limited water quality data indicate that Montezuma Creek and Verdure Creek are hard water streams with high alkalinities (Table 2.4) (Rust Geotech 1995a; Rust Geotech, Grand Junction, Colorado, unpublished data). Specific conductance is typically two to three times higher in Montezuma Creek than in Verdure Creek. Total dissolved solids often exceed the Utah State standard of 1200 mg/L, including the upstream Montezuma Creek reference site MZG (Crist and Trinca 1988; Rust Geotech 1995a; Rust Geotech,

Table 2.4. **Water quality and surface water and sediment contaminant data[a] for Montezuma Creek and Verdure Creek.** Values are means[b] with ranges in parentheses. Data are from samples collected in August, September, and/or October 1991-1995.

Analyte	Utah Standard[c]	MZG	MZ-2[d]	MZ-3[e]	MZ-5[f]	MZ-6	MZ-9	VD-1
Alkalinity (mg/L)		163 (123-201)	247	225.0	228.0	248 (237-267)	240	189 (178-210)
Ammonium (μg/L)		58.9 (19-160)	41.4	28.8	2680.0	1302.9 (69-2430)	1606 (952-2260)	19.6 (14-29)
Nitrate+Nitrite (μg/L as N)		534 (84.1-1040)	230	112	41	773 (67-1280)	1245 (1140-1350)	19 (10-36)
Specific Conductance (μmhos/cm)		1536 (1192-1880)	2002	1975	1267	1400 (1278-1496)	1344 (1265-1424)	671 (660-690)
Sulfate (mg/L)		738 (474-872)	872	880	272	379 (272-517)	308 (273-344)	129 (128-129)
Total Dissolved Solids (mg/L)	1200	1370 (914-1560)	1572 (1530-1620)	1647 (1610-1700)	-	1039 (968-1110)	975	-
pH	6.5-9.0	7.81-8.24	7.5-7.61	7.55-7.85	7.64-7.80	7.73-9.05	7.65-8.29	7.39-8.10
Aluminum								
Sediment (mg/kg)		-	16200	13500	18400	14400 (13700-15100)	12100	11200 (9960-12700)
Water (μg/L)		<51.9 (BD[g]-149)	BD	BD	BD	<281.9 (BD-1350)	<480.7 (BD-1410)	<89 (BD-186)
Arsenic								
Sediment (mg/kg)		-	5.7	11.2	7.3	6.0 (4.8-7.2)	18.1	4.5
Water (μg/L)	50 μg/L	BD	1.5	1.5	3.9	4.2 (2.5-5.6)	5.1 (4.3-5.9)	<1.2 (BD-1.4)
Boron								
Sediment (mg/kg)		-	7.9	3.7	9.8	6.4 (5.5-7.3)	5.1	4.1 (3.3-5.4)
Water (μg/L)	750 μg/L	43.6 (24.1-56.3)	59.2	65.9	235.0	166.4 (60.9-240.0)	233.0 (217.0-248.0)	30.6 (28.1-33.8)

Table 2.4 (continued)

Analyte	Utah Standard[c]	MZG	MZ-2[d]	MZ-3[e]	MZ-5[f]	MZ-6	MZ-9	VD-1
Potassium								
Water (mg/L)		2.7 (1.9-3.7)	4.3	4.8	9.8	8.2 (4.9-9.9)	9.6 (8.6-10.4)	1.6 (1.2-2.1)
Selenium								
Sediment (mg/kg)		-	BD	1.2	2.0	<1.25 (BD-1.5)	3.6	<0.3 (BD-0.5)
Water (μg/L)	10 μg/L	BD	2.3	3.0	BD	<2.0 (BD-3.7)	BD	BD
Sodium								
Water (mg/L)		28.0 (19.3-30.0)	78.5	83.6	93.9	96.1 (94.2-100.0)	97.4 (94.4-102.0)	28.4 (27.7-29.1)
Tin								
Sediment (mg/kg)		-	BD	BD	BD	BD	BD	BD
Water (μg/L)		BD	BD	BD	BD	BD	BD	BD
Uranium								
Water (μg/L)		3.4 (2.3-4.5)	202.0[f] (149-231)	266.3[i] (221-291)	-	181.0 (180-181)	-	-
Uranium-234								
Sediment (pCi/g)		-	4.7	5.6	6.2	3.9 (3.5-4.4)	6.7	1.3 (1.1-1.3)
Water (pCi/L)		3.3 (2.4-4.0)	62.9	64.2	13.8	33.3 (14.4-65.6)	18.3 (15.2-21.4)	0.9 (0.8-1.0)
Uranium-238								
Sediment (pCi/L)		-	5.5	6.1	6.3	4.1 (3.8-4.4)	7.2	1.4 (1.3-1.4)
Water (pCi/L)		1.5 (1.1-1.8)	63.3	66.6	14.2	35.1 (16.3-66.8)	19.2 (16.6-21.9)	BD

Table 2.4 (continued)

Analyte	Utah Standard[c]	MZG	MZ-2[d]	MZ-3[e]	MZ-5[f]	MZ-6	MZ-9	VD-1
Vanadium								
Sediment (mg/kg)		-	62.7	83.4	104.0	54.1 (51.5-56.8)	166.0	18.2 (15.9-20.2)
Water (μg/L)		BD	9.8	BD	BD	<15.8 (BD-28.9)	7.6 (6.0-8.8)	BD
Zinc								
Sediment (mg/kg)		-	56.2	60.2	53.4	41.7 (41.1-42.3)	69.5	39.7 (35.9-44.1)
Water (μg/L)	110 μg/L[j]	<7.8 (BD-18.8)	BD	BD	BD	<3.0 (BD-4.8)	<12.4 (BD-20.3)	14.6 (5.3-21.1)

[a]Source: Rust Geotech, Grand Junction, Colorado, Unpublished Data.

[b]Means are based on the results of 2 to 8 samples collected from 1991 through 1995; values without a range are for a single sample.

[c]State of Utah Water Quality Standards, Utah Administrative Code Rule 448-2.

[d]Unless otherwise noted, the water quality and sediment data for this site were obtained from the same approximate as the biological sampling site for MZ-2.

[e]Unless otherwise noted, the water quality and sediment data for this site were obtained from a location approximately 200 m upstream of the biological sampling site for MZ-3.

[f] Water quality and sediment data for this site were obtained from a location approximately 300 m upstream of the biological sampling site for MZ-5.

[g]BD = Below detection.

[h]Samples collected from a location approximately 150 m upstream of the biota site.

[i]Samples collected from a location approximately 350 m downstream of the biota site.

[j]Source: EPA 1986.

Both the high conductivities and total dissolved solids are thought to be caused by the percolation of water through the dam at Lloyds Lake which is constructed of gypsum laden Mancos shale (Crist and Trinca 1988). The pH in both streams typically ranges between 7.5 and 8.5, but at some locations in Montezuma Creek, pH values above the Utah maximum limit of 9.0 have been measured. Nitrate + nitrite concentrations are higher in Montezuma Creek than in Verdure Creek, and they are particularly high at MZ-9.

Some contaminants are elevated in the water and/or sediment at some areas downstream of the mill site including arsenic, copper, selenium, uranium, and vanadium (Table 2.4) (Rust Geotech 1995a; Rust Geotech, Grand Junction, Colorado, unpublished data). The measured concentrations of most contaminants appear to be well below Federal and State standards (Table 2.4).

3. METHODS

3.1 HABITAT ANALYSIS

As part of the environmental surveys of Montezuma Creek and Verdure Creek, a qualitative habitat evaluation index (QHEI) was determined for each sampling site. The QHEI is an index that incorporates information on 20 metrics including gradient, substrate, instream cover, channel morphology, channel stability, riparian zone development, pool quality, and riffle quality. It was originally developed by the Ohio Environmental Protection Agency (EPA) to assist in statewide biological monitoring surveys of water quality (Ohio EPA 1988; Rankin 1989). The QHEI is an effective and efficient tool for comparisons of overall habitat quality because it imposes the same review of various components at each site, has a built-in assessment of the relative value of each component, and requires few actual measurements of habitat variables. Despite relying on the subjective evaluation of the individual making the survey, the QHEI has been demonstrated to be fairly consistent for each surveyor (Rankin 1989), thus enhancing its utility for comparative evaluations. Although originally intended for use in Ohio, the QHEI should develop comparable scores for streams in Utah, with the understanding that total scores may not be directly comparable to scores for other states or regions.

The QHEI ratings were made on August 11 and 12 at MZ-2, MZ-3, MZ-5, MZ-9 and VD-1 using guidelines and forms provided by Ohio EPA (1989). Stream gradient was determined from topographic maps as specified by Ohio OEPA (1989). The rating scale for stream gradient was modified by a factor of 10 from the rating scale used by Ohio EPA (1989) because of the much greater relief present in Utah compared to Ohio.

Other habitat measurements were made as part of the fish community sampling. Following completion of fish sampling, the length, mean width, mean depth, and pool:riffle ratio of the sampling reach were measured at each quantitative site. The sample site elevation and watershed area were later determined from topographic maps.

3.2 MACROINVERTEBRATE BIOACCUMULATION

Macroinvertebrate samples for contaminant analysis were collected at a subset of the biological sampling sites (Table 2.1). An aquatic kick net fitted with a 500 μm-meshed net was used to collect macroinvertebrates at each site from a reach of approximately 100 m that included those portions where fish and/or macroinvertebrate community samples were collected. Collections were made by disturbing the bottom of the stream by foot or hand and allowing the dislodged invertebrates to float into the collection net. The invertebrates were immediately separated from the sample debris in plastic photographic trays at stream-side using forceps. Specimens were separated into cups of stream water by taxon and kept alive until a sufficient number of each taxon or functional feeding group was accumulated to satisfy the biomass requirements. When enough estimated biomass was accumulated, the specimens were placed on filter paper and blotted to remove visible moisture. The specimen groups were then weighed to the nearest 0.1 g on a Denver Instruments XE 3000D balance and counted (unless numerous small individuals were used), before being placed in EPA-approved vials kept on ice. An attempt was made to collect three composite samples of macroinvertebrates from each site, but at some sites only one or two samples were obtained due to the small number of target organisms available. Weights, numbers of specimens, taxa identifications and sample numbers were recorded in a laboratory notebook and the sample numbers were included on vial labels. The initial goal for sample composition was to select an equal biomass of the same taxa from each site, but changes in species composition prevented this. When the same taxa were not available, taxa within similar functional feeding groups were used as substitutes. Samples were thus composed of similar contributions of taxa or functional feeding groups. The functional feeding groups included detritivores (e.g., Tipulidae, Limnephilidae, Amphipoda), predators (e.g., *Argia*, Dytiscidae), and filter feeders (e.g., Hydropsycidae, Simuliidae) (see Appendix B, Table B.1). By including a range of functional feeding groups, it was hoped that the bioaccumulation sample would be representative of a wide range of possible exposure routes.

After collecting all samples they were placed in a sealed and labeled cooler with dry ice, shipped overnight to Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, and then stored in a standard freezer at −15 °C. The samples were later removed and the total contents weighed prior to drying in a Virtis Benchtop Freezedryer. The samples were reweighed after 72 h in the dryer and the percent moisture calculated for each sample (Appendix A). Because there were taxonomic differences among sites and water content can vary considerably between species, dry weight concentrations were used in all cases to make statistical comparisons among sites. Metal concentrations on a wet weight basis are also provided because they provide data necessary for ecological risk assessment. Samples were submitted to the Analytical Services Organization at the Oak Ridge K-25 Site in Oak Ridge, Tennessee for chemical and radiometric analysis. Sample chain of custody was maintained and documented from collection through analysis.

The samples were prepared at the analytical laboratory by High Pressure Ashing (HPA) using ALD procedure 100014 (Analytical Services Organization, Oak Ridge K-25 Site, Oak Ridge, Tennessee). Briefly, the samples were homogenized using an agate mortar and pestle, weighed, and placed into a 70-mL quartz HPA vessel with 5-mL of concentrated HNO_3 and 2.5-mL of concentrated HCl. The HPA ran through a time ramped temperature program for a total of 3 h in which the samples were taken to a temperature of 300 °C. The samples were limited in the amount available for analysis, therefore the amount used for preparation was approximately 0.25 g, the final volume of the preparation was 50-mL. Each homogenized sample was split three ways to generate a subsample for (1) inductively coupled plasma mass spectrometry (ICP/MS) analysis (EPA 200.8), (2) gross alpha and beta activity, and gamma spectroscopy, and (3) archival storage. For gamma spectroscopy, the digested sample was counted for 12 h in a Germanium detector. For gross alpha/beta analysis, the samples were counted on a gas proportional counter for 4 h.

Quality assurance was maintained by using replicate samples at each site, analysis of aquatic macroinvertebrates from reference areas (Verdure Creek in Utah and First Creek in east Tennessee), and determination of recoveries of analyte spikes. Aquatic macroinvertebrate samples were collected from First Creek in Tennessee (a stream having different hydrogeological conditions than the Utah sites) to evaluate whether the analytical methods were sensitive enough to distinguish an expected different pattern of metal contamination. Quality assurance results are summarized in Appendix A.

Statistical procedures were conducted to evaluate site differences in metal accumulation, but the results of these analyses should be interpreted with caution. Many factors could skew the outcome of the statistical analyses and result in misinterpretation, including the small number of samples obtained (1-3 samples per site), the use of only one appropriate reference site, the unknown intra-site variability, and the collection of different species at each site. However, these uncertainties could not be avoided, and statistical measures were considered useful for evaluating the relative potential importance of various metals. For example, a metal with significant site-to-site differences may be of greater concern than a metal with no significant site-to-site differences. Statistical evaluations of data were made using SAS procedures and software (SAS 1985a, 1985b) for analysis of the variance (ANOVA, General Linear Models procedure), Tukey's multiple comparison test, and calculation of the mean, standard deviation (SD), standard error (SE), and coefficient of variation (CV). Tests for homogeneity of variance among various data groups were conducted using Levene's test on untransformed and $\log_e$-transformed variables (Sokal and Rohlf 1981). Comparisons were based on untransformed data unless Levene's test indicated that transformation was needed to meet assumptions of homogeneous variances. Dunnett's test was used to compare Montezuma Creek site means with the reference stream values (Zar 1984). Only the local reference stream (Verdure Creek) was used for the statistical comparisons. When contaminant values did not exceed the detection limits, values were halved before making statistical comparisons. All comparisons were conducted using α = 0.05.

3.3 BENTHIC MACROINVERTEBRATE COMMUNITY

3.3.1 Quantitative Sample Collection

Quantitative benthic macroinvertebrate samples were collected from seven sites over a two-day period (August 11 and 12, 1995) (Table 2.1; Fig. 2.1). A Surber sampler (0.09 m^2 or 1 ft^2) equipped with a 363-µm mesh net was used to collect samples in triplicate at randomly selected locations within a riffle at each site. Each sample was placed into a polyurethane-coated glass jar and preserved in 95% ethanol to compensate for dilution by associated stream water. After all samples were collected, they were shipped to a laboratory in Oak Ridge, Tennessee, for processing. A detailed description of procedures employed for site evaluation and sample collection, storage, and maintenance can be found in Smith (1992).

In the laboratory, samples were placed in a U. S. Standard No. 60-mesh (250-µm openings) sieve and rinsed with tap water. Small aliquots of a sample were then placed in a white plastic tray partially filled with water, and the organisms were removed from the sample debris with forceps. This process was repeated with the remaining contents of each sample until entirely sorted. Organisms were identified to the lowest practical taxon which was genus for most taxa, but the Chironomidae were identified to subfamily or tribe, and the Oligochaeta and a few other non-insect taxa were identified to class or order only. The individuals within each taxon were then enumerated. Details of laboratory sample processing are given in Wojtowicz and Smith (1992).

Data were analyzed with Statistical Analysis System software and procedures (SAS 1985a, 1985b). Variation among sites for each metric measured was determined with a one-way analysis of variance (ANOVA). If the ANOVA indicated significant site effects (i.e., $p \leq 0.05$), differences were separated with a Tukey's Studentized Range test ($\alpha = 0.05$). Values for all metrics examined with an ANOVA were transformed to correct for heteroscedasticity as recommended by Elliot (1977). Density values were transformed with $\log_{10}(X+1)$, and richness values were transformed with the square root of X+0.5, where X was the individual observed values for each metric. Untransformed means and standard errors are given in tables and figures.

3.3.2 Qualitative Sample Collection

A single qualitative sample was collected from each of two pond sites in Montezuma Creek: the large beaver pond at transect 5, or MZ-5P and the Stock Pond near the mill site boundary (Table 2.1; Fig. 2.1). All distinct habitat types were sampled for macroinvertebrates with a D-frame aquatic kick net fitted with a 500 μm-meshed net. After sampling each habitat type, the material retained in the collection net was placed into a white, plastic tray at streamside, and several representatives of all distinct taxa were placed into a polyurethane-coated container of 95% ethanol; organisms from all habitat types were composited in the same sample container. Approximately seven man hours were spent at each site in collecting and field sorting samples. The collected organisms were shipped to a laboratory in Oak Ridge, Tennessee, for identification. The level of identifications were the same as those for the quantitative macroinvertebrate samples.

3.4 FISH COMMUNITY

3.4.1 Quantitative Fish Collections

Quantitative sampling of the fish populations at four sites in the Montezuma Creek watershed and at one site in a reference stream, Verdure Creek, was conducted by electrofishing with one Smith-Root backpack electrofisher on August 14-16, 1995 (Table 2.1; Figs. 2.1). At each site, a stream length of 70 to 164 m was sampled, with greater lengths covered at downstream sites and VD-1. After 0.64-cm-mesh seines were placed across the upper and lower boundaries of the fish sampling site to restrict fish movement, a two- to four-person sampling team electrofished the site in an upstream direction for up to three consecutive passes. If fish were not collected on the first pass, then further passes were not made. Stunned fish were collected and stored by pass in buckets during further sampling. Following the electrofishing, fish were anesthetized with MS-222 (tricaine methanesulfonate), identified, measured (total length), and weighed using Pesola spring scales. After processing fish from all passes, the fish were allowed to fully recover from the anesthesia and returned to the stream. Quantitative species population estimates were calculated using the maximum weighted likelihood method of Carle and Strub (1978). Biomass for each species was estimated by multiplying the population estimate by the mean weight per size class. To calculate density and biomass per unit area, total numbers and biomass were divided by the surface area (m^2) of the study reach. These data were compiled and analyzed by a comprehensive Fortran 77 program developed by staff of ORNL's Environmental Sciences Division (ESD) (Railsback et al. 1989).

3.4.2 Qualitative Fish Collections

Qualitative fish sampling at four sites in Montezuma Creek was conducted by electrofishing and/or seining (Table 2.1; Figs. 2.1). At the MZ-5P site, repeated seine hauls with a 6-m seine were made by a two-person crew to cover all available habitat within the pond. At MZ-9, a four-person crew electrofished in an upstream direction with a Smith-Root backpack electrofisher. At MZVD, a four-person sampling team electrofished and seined upstream using a Smith-Root backpack electrofisher and a 6-m seine. Captured fish were placed in buckets, identified, and released except for a small subsample that was preserved in 10% formaldehyde and shipped to an ESD laboratory in Oak Ridge, Tennessee, for positive identification. The duration of the electrofishing effort (in minutes) and/or the length of stream (in meters) sampled were recorded. Data from these samples were used to determine the species richness and number of specimens (relative abundance) based on sampling effort per minute. All field sampling was conducted according to standard operating procedures (Schilling et al. 1996).

4. RESULTS

4.1 HABITAT

The QHEI ratings for the Montezuma Creek sites indicated the presence of high quality habitat (Table 4.1). The overall scores ranged from a low of 71.0 at MZ-2 up to 91.5 at MZ-9. The score for Verdure Creek was also very high at 83.5. These ratings would be considered in the exceptional range (Rankin 1989) with excellent habitat heterogeneity. The individual components indicate that most sites had a wide variety of microhabitats and abundant instream cover. The weakest aspects of the habitat were moderate substrate embeddedness and narrow riparian zones at the two upper sites, MZ-2 and MZ-3.

Table 4.1. Habitat analysis of Montezuma Creek and Verdure Creek sites based on Qualitative Habitat Evaluation Index (QHEI)[a].

Parameter	Site/Habitat Variable Description (numerical score for QHEI)[b]				
	MZ-2	MZ-3	MZ-5	MZ-9	VD-1
Primary Substrate Type	Cobble-Muck (10)	Boulder-Cobble (17)	Cobble -Hardpan (12)	Boulder-Cobble (17)	Boulder-Cobble (17)
Number of Substrates	5 (2)	5 (2)	5 (2)	5 (2)	5 (2)
Substrate Quality	Sandstone (0)	Sandstone (0)	Sandstone-Hardpan (0)	Sandstone (0)	Sandstone (0)
Substrate Embeddedness	Moderate (-2)	Moderate (-2)	Moderate-Extensive(-3)	Moderate-Low (-0.5)	Normal (0)
Instream Cover Types	7 (7)	8 (8)	6 (6)	6 (6)	6 (6)
Instream Cover Amount	Extensive (11)	Extensive (11)	Extensive (11)	Extensive (11)	Extensive (11)
Channel Sinuosity	Mod (3)	Low (2)	Moderate (3)	Moderate (3)	Moderate (3)
Channel Development	Good (5)	Good (5)	Good-Fair (4)	Excellent (7)	Good (5)
Channelization	None (6)	None (6)	None (6)	None (6)	None (6)
Channel Stability	Moderate (2)	High (3)	Moderate (2)	High (3)	High (3)
Riparian Width	Narrow (2)	Narrow (2)	Narrow-Wide (3)	Wide (4)	Wide (4)
Riparian Cover	Fenced Pasture (2)	Fenced Pasture (2)	Shrub -Old Field (4)	Pasture-Shrub (2)	Forest-Shrub (5)
Bank Erosion	Moderate (4)	Little-Moderate (5)	Little-Moderate (5)	None (6)	Little-Moderate (5)
Pool Depth (m)	0.4-0.7 (2)	0.7-1.0 (4)	0.4-0.7 (2)	0.7-1.0 (4)	0.4-0.7 (2)
Pool-Riffle Width	Pool>riffle (2)	Pool>riffle (2)	Pool≥riffle (1.5)	Pool>riffle (2)	Pool≥riffle (1.5)
Current Velocity	4 types (4)	4 types (4)	4 types (4)	5 types (3)	4 types (4)
Riffle Depth (cm)	10-50 (3)	5-50 (2)	10-50 (3)	10- >50 (4)	5-10 (1)
Riffle Stability	Stable (2)	Stable (2)	Unstable (0)	Stable (2)	Stable (2)
Riffle Embeddedness	Moderate (0)	Low-Moderate (-0.5)	Extensive (-1)	Moderate (0)	Moderate (0)
Gradient	Low-Moderate (6)	Moderate (8)	Moderate (8)	High (10)	Low-Moderate (6)
TOTAL	71.0	82.5	72.5	91.5	83.5

[a]QHEI based on methodology from Ohio EPA (1989).
[b]Values in parentheses represent the individual metric scores.

macroinvertebrate and fish communities throughout Montezuma Creek.

Other habitat data indicated that all sampling sites were similar in width and depth, although Verdure Creek was shallower and narrower than the Montezuma Creek sites (Table 2.2). The smaller size of VD-1 corresponds with a smaller watershed area, lower gradient, and higher pool:riffle ratio.

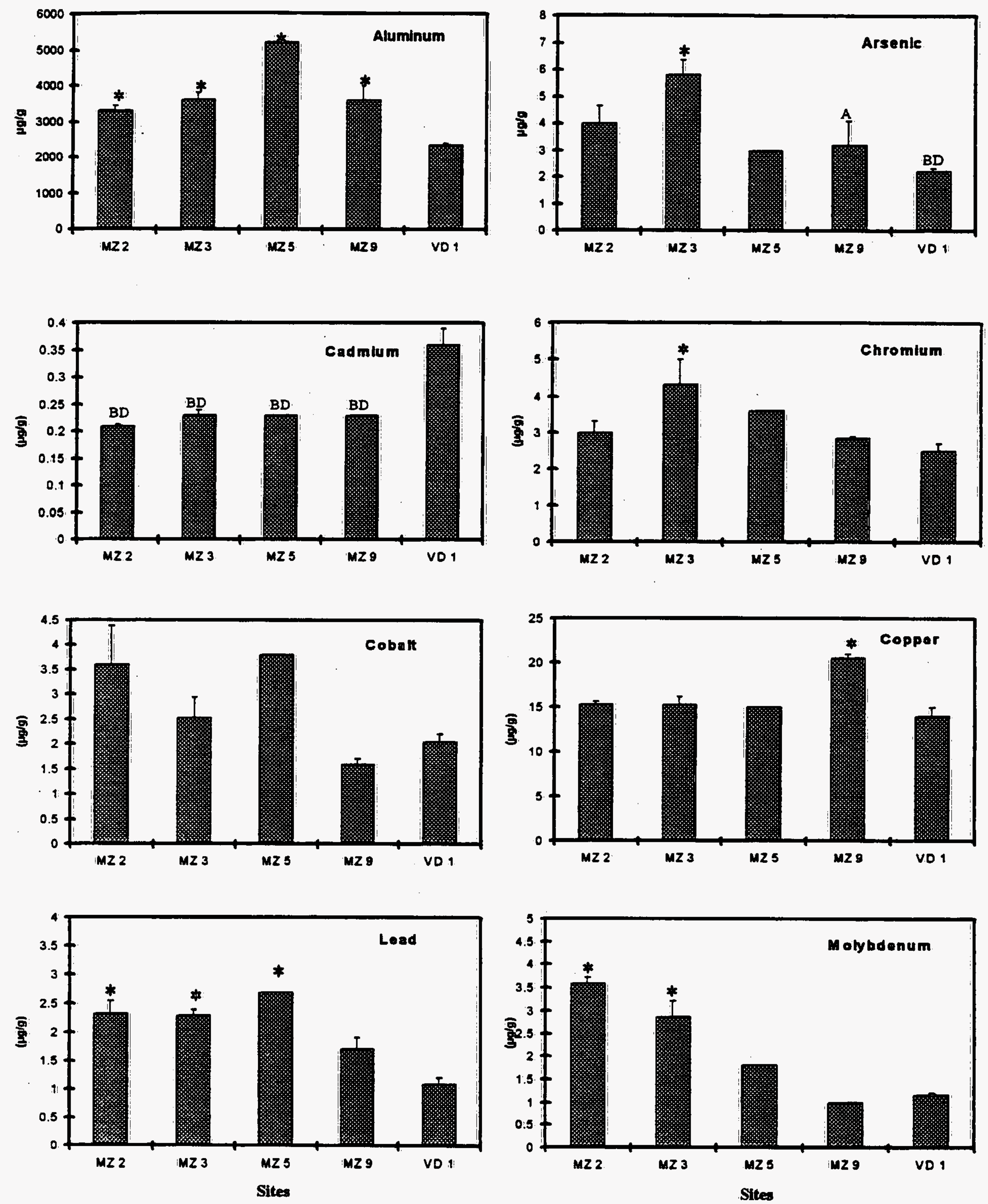
4.2 AQUATIC MACROINVERTEBRATE BIOACCUMULATION

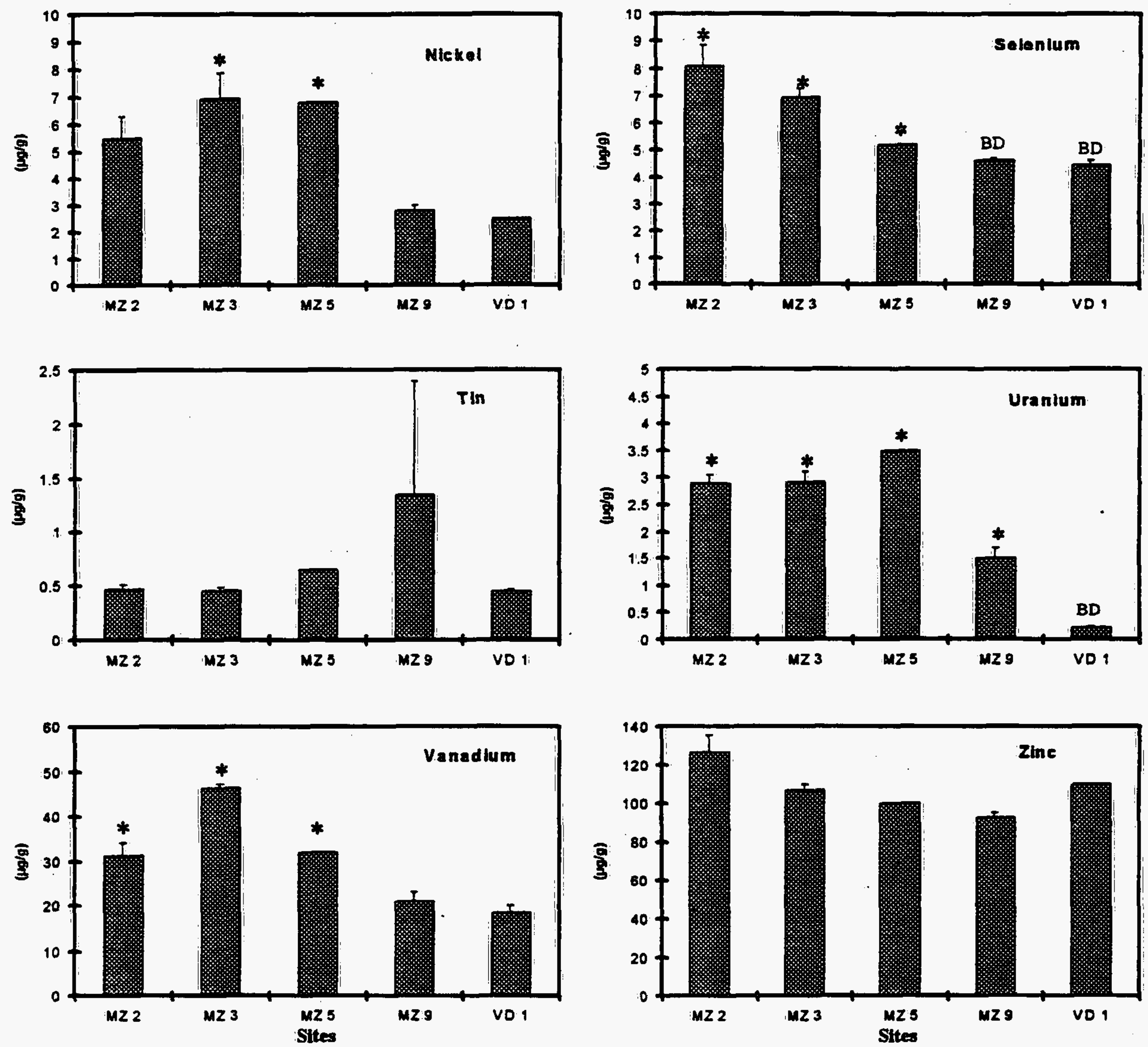
Concentrations of 15 metals in composite samples of aquatic macroinvertebrates collected from sites in Montezuma Creek and two reference areas are reported in Appendix B, Tables B.1 and B.2 (dry wt. basis) and B.3 (wet wt. basis). Detectable concentrations of most metals were found in invertebrates from Montezuma Creek. All values that were at the detection limit obtained by the ICP/MS procedure were below those requested in the sampling and analysis plan (Rust Geotech 1995b) except for four selenium values for which the level of detection exceeded the requested limit by an average of 0.08 µg/g (8%).

Concentrations of lead, molybdenum, nickel, selenium, uranium, and vanadium were clearly elevated in invertebrates collected from the three sites in Montezuma Creek nearest to the mill site compared with invertebrates collected further downstream and from Verdure Creek (Fig. 4.1). Concentrations of these metals in invertebrates from upstream sites (MZ-2, MZ-3, and MZ-5) were generally 2-3 times higher than from Verdure Creek, except for uranium, which was at least 13 times higher in invertebrates at sites near the mill site. Aluminum was also higher at all Montezuma Creek sites in comparison to Verdure Creek, but there was no significant difference between upstream and downstream locations in Montezuma Creek (Tukey's test; Table 4.2). The following metals in invertebrates from Montezuma Creek showed no conclusive spatial pattern of contamination although there were elevated concentrations at some sites: arsenic, beryllium, cadmium, chromium, cobalt, copper, tin, and zinc (Fig. 4.1).

A pattern of steadily decreasing concentrations in invertebrates with increasing distance from the mill

Fig. 4.1. Mean metal concentrations (µg/g, dry weight) in composite samples of aquatic macroinvertebrates from Montezuma Creek and Verdure Creek, August 1995.





Note:

- Beryllium not shown because all concentrations reported were below the limit of detection.
- '*' indicates mean concentration is significantly higher than the reference site (VD 1). Dunnett's test was used to test for significant differences between MZ sites and the reference site.
- 'A' indicates 1 of 2 samples less than the detection limit. Half the detection limit value was used to conduct all statistical analyses.
- 'BD' indicates all samples were below limit of detection.
- Vertical bars represent + 1 SE.
- Concentrations reported are in µg/g for dry weight samples.
- MZ = Montezuma Creek followed by the biological study area number. #2 represents the most upstream site and #9 the most downstream site. VD 1 = Verdure Creek biological study area #1. This is the reference site.

Table 4.2. Tukey's multiple comparison test of site differences in mean metal concentrations of aquatic macroinvertebrates in Montezuma Creek, August 1995. Mean concentrations ($\mu g/g$, dry wt.) are given in parenthesis. Mean concentrations are similar at sites having the same letter grouping, $\alpha > 0.05$.

	Analytes					
Sites[a,b]	Al	Cu	Mo	Se	U	V
MZ-2	B (3300)	B (15.33)	A (3.60)	A (8.07)	A (2.90)	B (31.33)
MZ-3	B (3600)	B (15.33)	AB (2.87)	A (6.93)	A (2.93)	A (46.33)
MZ-5	A (5200)	B (15.00)	BC (1.80)	AB (5.20)	A (3.50)	B (32.00)
MZ-9	B (3600)	A (20.50)	C (1.00)	B (<4.6)	B (1.50)	B (21.00)

[a]No significant differences were observed among sites for other metals analyzed: arsenic, beryllium, cadmium, chromium, cobalt, lead, nickel, tin, and zinc.

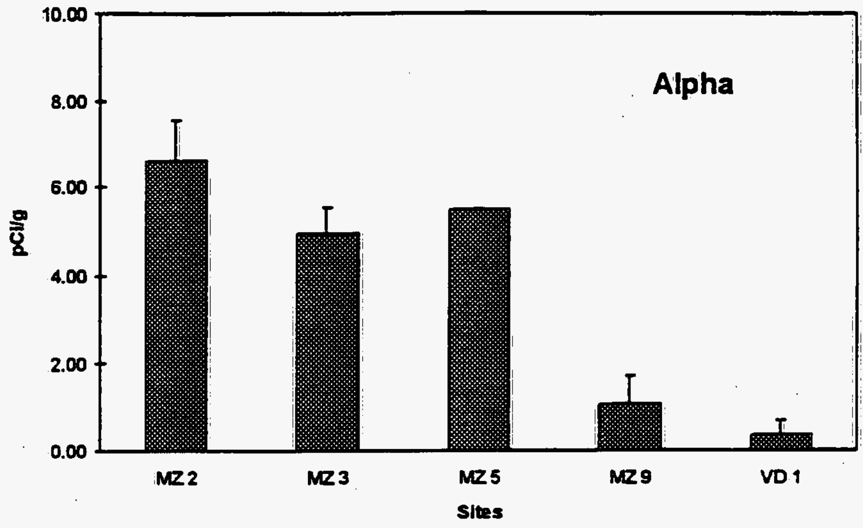
[b]MZ = Montezuma Creek followed by the biological study area number. #2 represents the most upstream site and #9 the most downstream site.

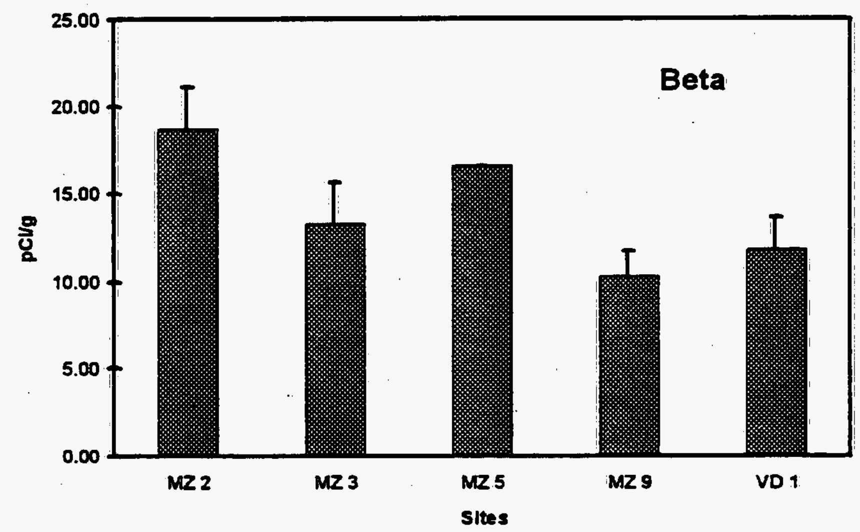
site was most striking for selenium and molybdenum (Fig. 4.1; Table 4.2). Although uranium and lead concentrations in invertebrates were substantially lower at the most downstream Montezuma Creek site (MZ-9), there was little difference in mean concentrations of these metals among the three upstream sites (MZ-2, MZ-3, and MZ-5). The relative closeness of these three sites or possibly the diffuse nature of the source(s) of these contaminants may help explain the absence of a distinct spatial pattern in this reach. A perceptible increase in average concentrations of arsenic, chromium, nickel, and vanadium was apparent in invertebrates from MZ-3 in comparison to MZ-2, suggesting an additional source(s) of these metals between MZ-2 and MZ-3. However, when the concentrations in invertebrates from Montezuma Creek sites only were statistically compared, only vanadium was significantly higher at MZ-3 than the other sites (Tukey's test; Table 4.2).

In comparison to Verdure Creek, concentrations of uranium in invertebrates from Montezuma Creek appeared to be the most elevated of the metals possibly associated with the mill site (Table B.3; Fig. 4.1). The gross alpha activity measured in invertebrates from Montezuma Creek appears to mirror the site-to-site pattern of uranium contamination (Fig. 4.2). Gross alpha activity of invertebrate samples collected at the three sites in Montezuma Creek closest to the Monticello Mill Site was strikingly higher than that of samples from further downstream or the reference stream, Verdure Creek (Fig. 4.2; Table B.4). Average gross alpha activity (± SE) in the samples from the three sites nearest the mill site was 5.7 ± 0.5 pCi/g dry wt. versus 0.7 ± 0.3 pCi/g dry wt. for the more remote sites. None of the individual values comprising the latter group exceeded the 95% confidence interval of the radiometric counting procedure (background). The mean uranium concentration of the samples from the three upper sites was 3.0 ± 0.12 μg/g dry wt. Assuming that the uranium is present at its natural isotopic abundance ratios, approximately 37% (2.1 pCi/g) of the gross alpha activity of the samples can be attributed to their uranium content.

Gross beta activity was also higher in the samples from the upper three sites than in the two remote

Fig. 4.2 Mean gross alpha and gross beta activity (pCi/g, dry weight) in aquatic macroinvertebrates collected from Montizuma Creek and Verdure Creek, August 1995.





Note:

- MZ = Montezuma Creek followed by the biological study area number. #2 represents the most upstream site and #9 the most downstream site. VD 1 = Verdure Creek biological study area #1. This is the reference site.

- Vertical bars represent + 1 SE.

- Values reported are in pCi/g for dry weight samples.

sites (Table B.4; Fig. 4.2), averaging 16.1 ± 1.6 pCi/g versus 8.5 ± 3.0 pCi/g. The smaller difference between the upper sites and the more remote sites is likely related to the importance of natural potassium-40, which is highly bioaccumulated, as a source of beta activity in organisms and the apparent low bioaccumulation potential of other beta emitters in Montezuma Creek. If the excess beta activity (difference between upper sites and remote sites) in invertebrates is adjusted to wet wt. basis and used to calculate a bioconcentration factor, values of 25 -50 are obtained.

Gamma spectroscopy was not able to conclusively detect radioisotopes in invertebrate samples at concentrations above background levels (Appendix B.4). Error terms were high in comparison to the measured values and many sample results were less than the confidence level of 95%.

4.3 BENTHIC MACROINVERTEBRATE COMMUNITY

4.3.1 Montezuma Creek

4.3.1.1 Community structure

Total densities of the benthic macroinvertebrates in Montezuma Creek and Verdure Creek varied significantly (Fig. 4.3; Table 4.3). Except for MZ-6, total densities at all sites downstream of the mill site were significantly higher than at either reference site (MZG and VD-1), but even the mean density at MZ-6 was approximately three times higher than at the reference sites. The combined densities of the mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (i.e., EPT density) also varied significantly among sites (Fig. 4.3; Table 4.3). Lowest EPT densities were also observed at the reference sites, but only the differences between MZ-9 and the reference sites were statistically detectable.

Differences among sites in total taxonomic richness were considerably less than those for

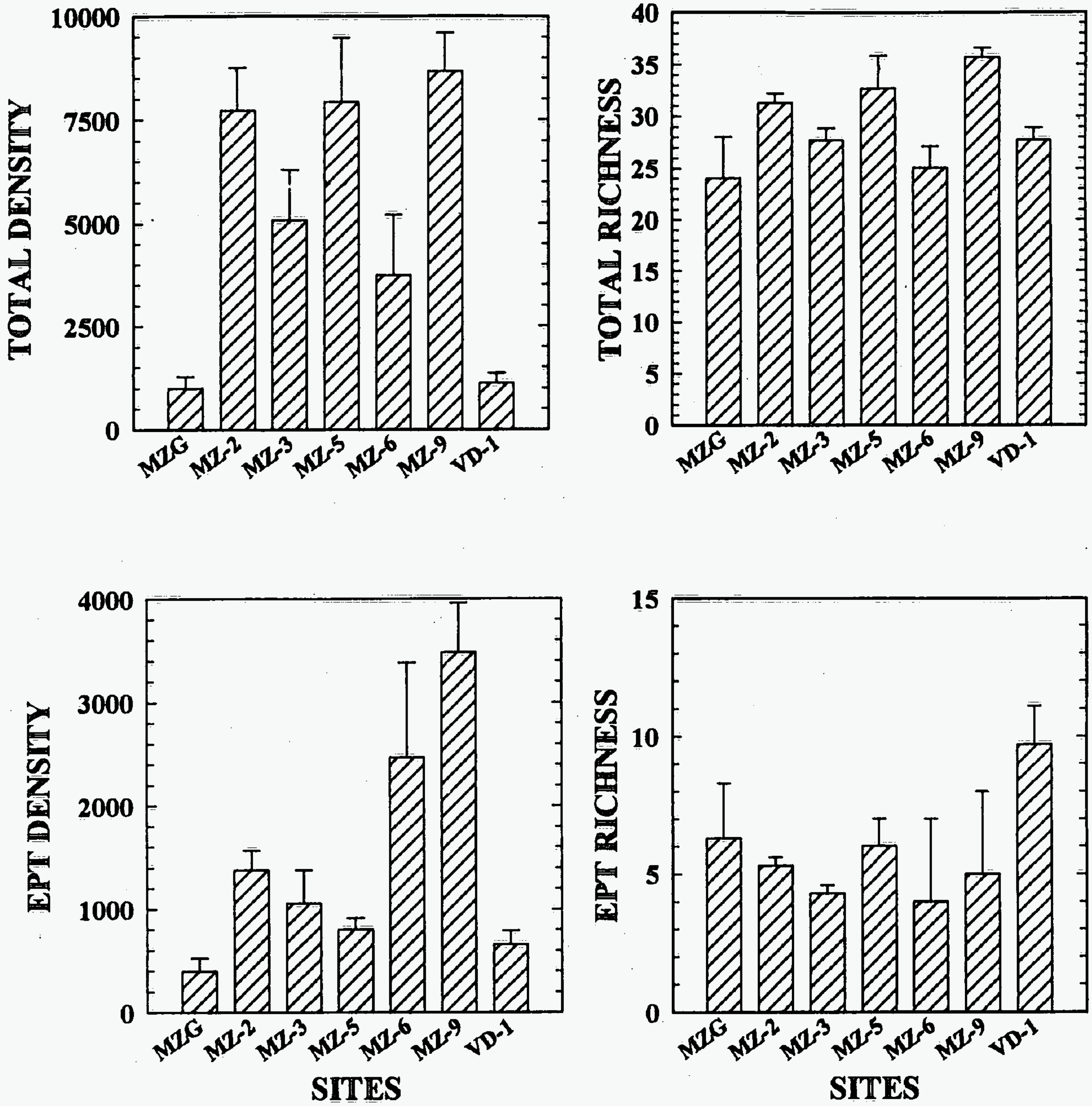


Fig. 4.3. Total density (number of individuals/0.1 m²), total combined density of the Ephemeroptera, Plecoptera, and Trichoptera (number of EPT individuals/0.1 m²), total taxonomic richness (number of taxa/sample), and total EPT richness (number of EPT taxa/sample), in Montezuma Creek and Verdure Creek, Monticello, Utah. Values are means ± 1 SE; n=3.

Table 4.3. Results of one-way ANOVA (site) and Tukey's multiple range test for total density, EPT density, total richness, EPT richness, densities and richness of the mayflies, stoneflies and caddisflies, and densities of selected numerically dominant taxa.
Sites joined by the same line were not significantly different ($\alpha < 0.05$).

	Sites	F-value[a]	p-value
Total density	MZ-9 MZ-5 MZ-2 MZ-3 MZ-6 VD-1 MZG	12.80	0.0001
Total richness	MZ-9 MZ-5 MZ-2 MZ-3 VD-1 MZ-6 MZG	3.33	0.0300
EPT density	MZ-9 MZ-6 MZ-2 MZ-3 MZ-5 VD-1 MZG	7.97	0.0007
EPT richness	VD-1 MZG MZ-5 MZ-2 MZ-9 MZ-3 MZ-6	3.26	0.0319
Mayfly density	MZ-9 MZ-6 MZ-3 MZ-5 VD-1 MZG MZ-2	10.49	0.0002
Mayfly richness	VD-1 MZG MZ-5 MZ-6 MZ-2 MZ-3 MZ-9	14.28	0.0001
Stonefly density	VD-1 MZG	8.88	0.0407
Stonefly richness	VD-1 MZG	3.97	0.1171
Trichoptera density	MZ-2 MZ-9 MZ-6 MZ-5 VD-1 MZ-3 MZG	8.47	0.0005
Trichoptera richness	MZ-5 MZ-2 MZ-9 VD-1 MZ-3 MZ-6 MZG	0.92	0.5120
Orthocladiinae density	MZ-5 MZ-2 MZ-9 MZ-3 VD-1 MZ-6 MZG	9.88	0.0002
Tanytarsini density	MZ-9 MZ-5 MZ-2 MZ-6 VD-1 MZ-3 MZG	4.49	0.0097
Oligochaeta density	MZ-2 MZ-3 MZ-5 MZ-9 MZG VD-1 MZ-6	12.22	0.0001
Physella density	MZ2 MZ-3 MZ-6 MZ-9 MZ-5 VD-1 MZG	35.06	0.0001
Baetis density	MZ-9 MZ-6 MZ-3 MZ-5 VD-1 MZG MZ2	10.46	0.0002
Simulium density	MZ-5 MZ-9 MZ-3 MZ-6 MZ-2 MZG VD-1	9.61	0.0003

[a]Degrees of freedom for all evaluated metrics except stonefly density and richness were 6, 14 (numerator, demoninator). Degrees of freedom for stonefly density and richness were 1, 4.

density, with values for no site differing by more than 1.5 fold (Fig. 4.3; Table 4.3). The only statistically detectable difference was between MZG and MZ-9, with richness being highest at MZ-9. The combined richness of the mayflies, stoneflies, and caddisflies (EPT richness) exhibited significant spatial variation, but as for total richness spatial differences tended not to be as large as those for densities (Fig. 4.3; Table 4.3). EPT richness values at those sites downstream of the mill site did not differ significantly from that of the upstream reference at MZG. However, EPT richness at the Verdure Creek reference site was significantly higher than at all sites downstream of the mill site. Neither total nor EPT richness exhibited any clear spatial trends indicating that conditions were changing with distance of the mill site.

Highly significant spatial variation was exhibited in density estimates for mayflies and caddisflies (Fig. 4.4; Table 4.3). Densities of mayflies at MZ-9 and MZ-6 were significantly higher than at either reference site, and all sites downstream of the mill site had significantly higher densities of caddisflies than at MZG except for MZ-3. In general, densities for these two orders of insects increased with distance from the upstream reference site MZG except for caddisfly densities at MZ-2 which were almost two times higher than at all other sites. In contrast to densities, caddisfly taxonomic richness exhibited no clear spatial trends (Fig. 4.4; Table 4.3). Mayfly richness on the other hand was significantly higher at both reference sites than at all Montezuma Creek sites downstream of the mill site except MZ-5, while mayfly richness at MZ-5 was significantly lower than at Verdure Creek (Fig. 4.4; Table 4.3).

Stoneflies were not collected at any sites in Montezuma Creek downstream of the mill site (Fig. 4.4). Although stoneflies were collected at the two reference sites, their densities were very low, ranging from about 1 individual/0.1 m^2 at MZG to about 4 individuals/0.1 m^2 at VD-1. Richness of this group was similarly low at the two reference sites, with two or fewer different taxa generally being collected in each sample.

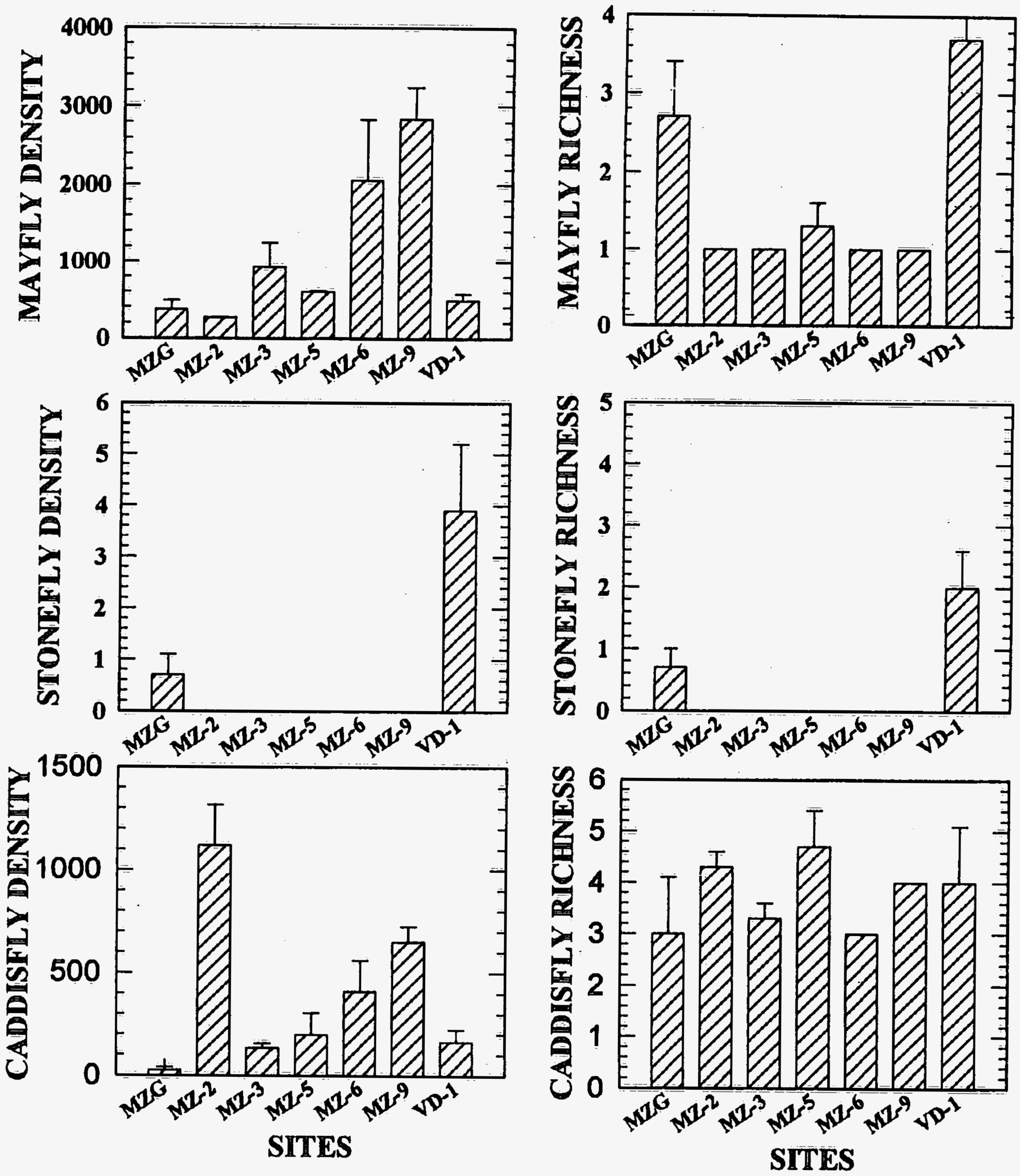


Fig. 4.4. Total densities (number of individuals/0.1 m^2) and taxonomic richness (number of taxa/sample) of the mayfiles (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) in Montezuma Creek and Verdure Creek, Monticello, Utah. Values are means ± 1 SE; n=3.

4.3.1.2 Community composition

A checklist of benthic macroinvertebrates collected in Montezuma Creek and Verdure Creek is given in Appendix C, Table C.1, and a copy of the raw data are in Appendix D. Combined, the mayflies, stoneflies, and caddisflies (EPT taxa) accounted for over 11% of the total community density at all Montezuma Creek sites and Verdure Creek (Fig. 4.5), but as previously pointed out, the stoneflies contributed little or none to combined EPT densities. The relative abundances of the chironomids (non-biting midges) were similar at MZ-2, MZ-3, MZ-5, MZ-9, and the reference site VD-1, while the relative abundances of this group at MZ-6 and MZG were comparable. The Diptera (true flies) were the most abundant taxonomic group at MZ-5, but they also accounted for over 20% of the total densities at MZ-3 and MZ-9. The oligochaetes (segmented worms) were the most numerically dominant at MZ-2, and their relative abundance showed a trend of decreasing with increasing distance downstream.

4.3.1.3 Numerically dominant taxa

Most sites were characterized by high densities of only a few taxa. High densities of chironomid (non-biting midges) within the subfamily Orthocladiinae and the tribe Tanytarsini were observed at some Montezuma Creek sites downstream of the mill site (Fig. 4.6). Significant spatial variation was exhibited among the sites in both of these groups (Table 4.3). Densities of the Orthocladiinae were significantly higher at MZ-2, MZ-5, and MZ-9 than at either reference site. Densities of the Orthocladiinae at MZ-3 and Verdure Creek were statistically indistinguishable even though mean density values more than five times higher at MZ-3. The extensive variation exhibited among sample replicates in Orthocladiinae densities at MZ-3 most likely limited the statistical test's power to separate any potential difference between these sites (Fig. 4.6). A difference of at least 18 fold existed between MZ-5 and MZ-9 and the two reference sites in densities of the

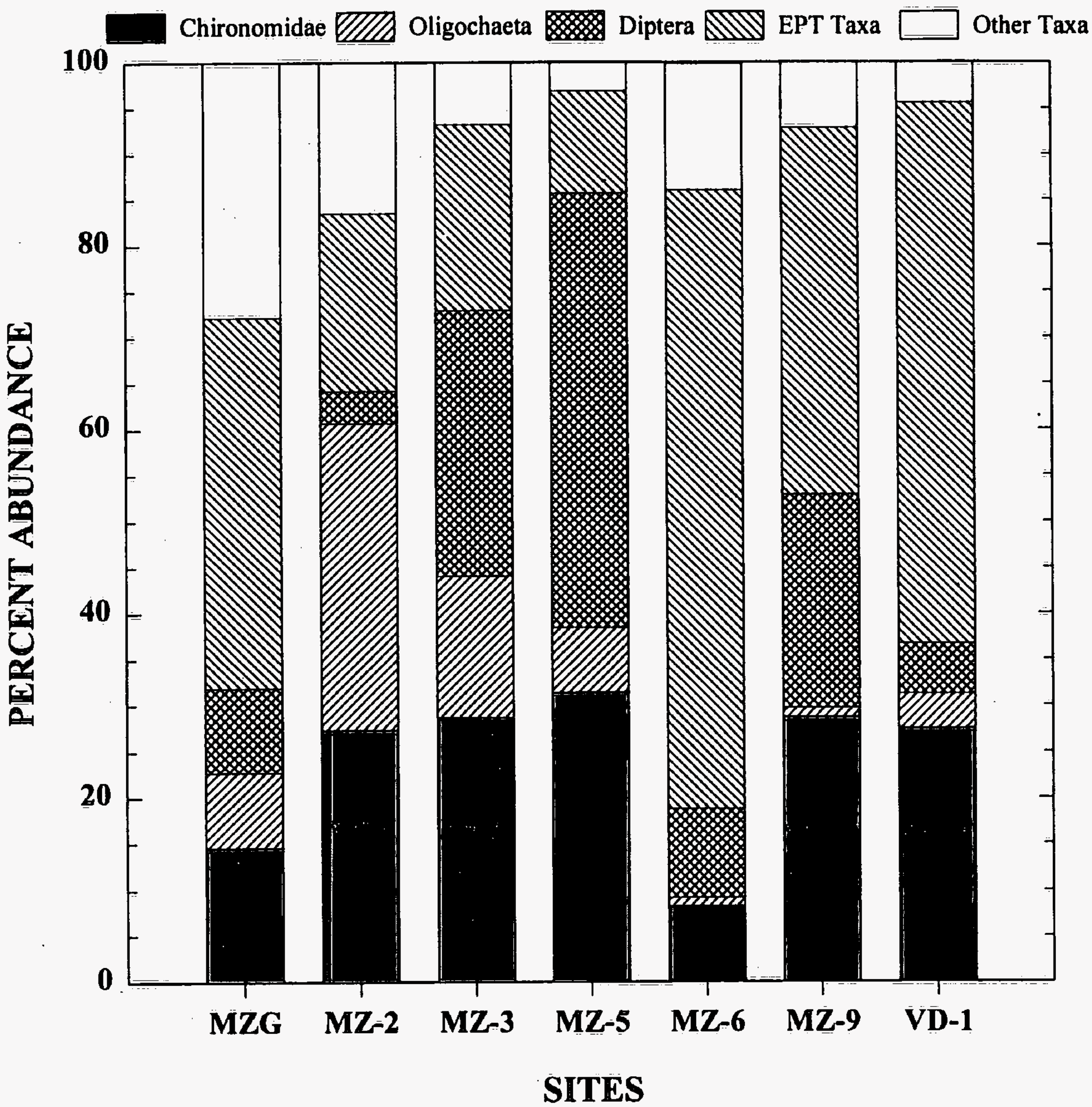


Fig. 4.5. Percent abundance (percent of total density) of selected macroinvertebrate taxa in Montezuma Creek and Verdure Creek, Monticello, Utah.

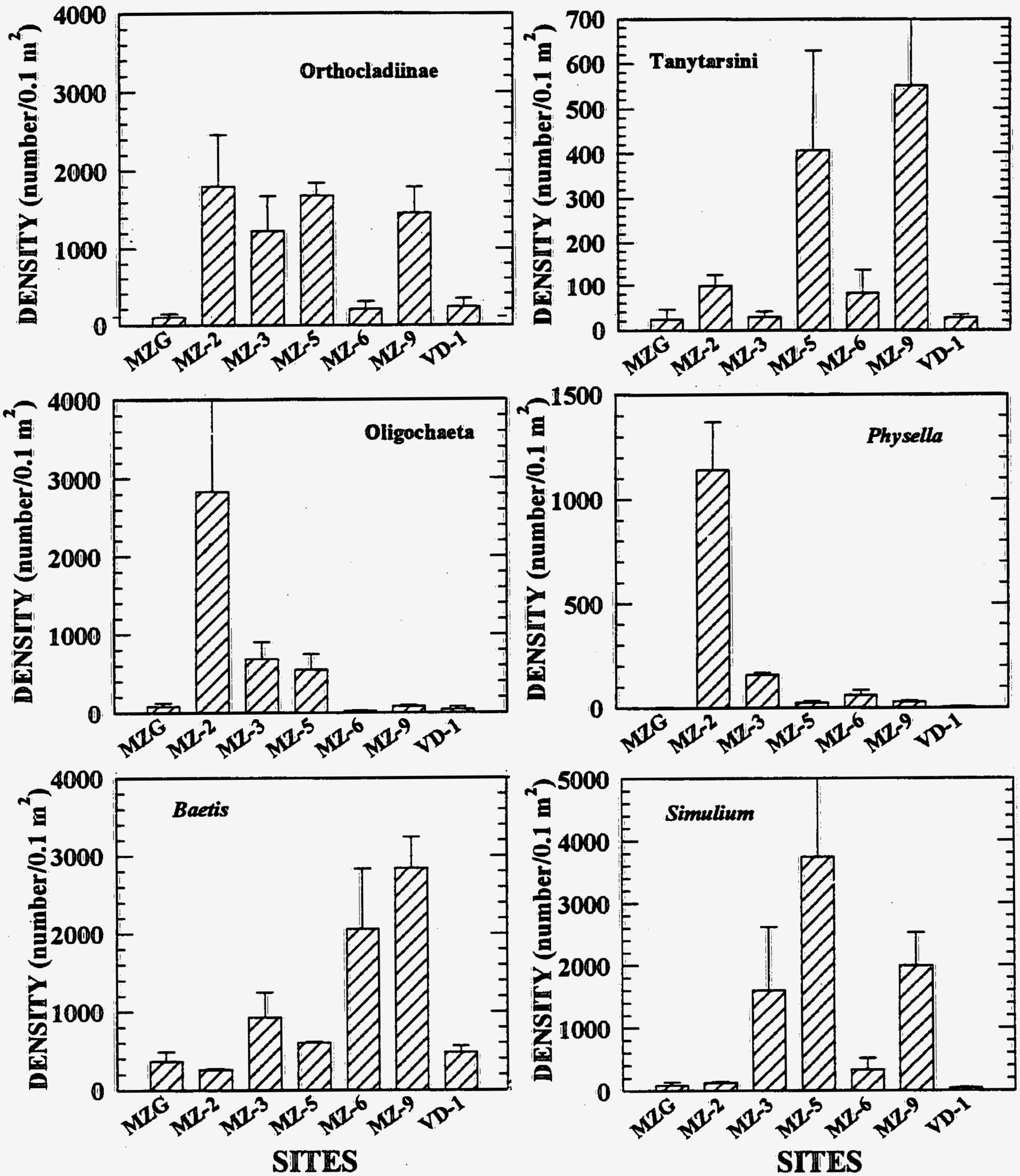


Fig. 4.6. Total densities of numerically dominant macroinvertebrate taxa in Montezuma Creek and Verdure Creek, Monticello, Utah. Values are means ± 1 SE; n=3.

Montezuma Creek is included with the taxonomic checklist for the stream sites in Table C.1. A copy of the raw data set is given in Appendix E. A total of 36 and 50 taxa were collected from the Stock Pond and beaver pond respectively. Of the taxa collected from the Stock Pond, 18 were benthic, two were clingers/benthic which spend much of their time attached to algae, macrophytes or other debris on the bottom of standing water, and 16 were swimmers that generally stay suspended in the water column at all times, or swimmers/clingers that generally swim in the water column and cling to materials such as sticks and macrophytes. In the Beaver Pond, 25 of the taxa collected were benthic, 21 were swimmers or swimmers/clingers, one was a surface dweller, and two were clingers/benthic.

4.4 Fish Community

Quantitative and qualitative surveys of sites on Montezuma Creek failed to find fish at sites above the confluence with Verdure Creek. Given the amount of stream sampled and the variety of habitats covered during sampling, the absence of fish in the surveys would not be a result of insufficient sampling effort. During the quantitative survey of MZ-5 and the qualitative survey of MZ-5P beaver pond, several tiger salamander (*Ambystoma tigrinum*) larvae were collected. The qualitative survey of lower Montezuma Creek at MZVD, found only one species of fish, the speckled dace (*Rhinichthys osculus*). A total of 246 specimens of dace were collected with a catch per unit effort of 5.2 fish/min. The quantitative survey of VD-1 again found only one species of fish, the rainbow trout (*Oncorhynchus mykiss*). A total of 16 trout were captured with an average density of 0.05 fish/m^2. The trout had a total biomass of 5.11 g/m^2 with specimens ranging from 14.7 to 30.4 cm in total length. Observations of Verdure Creek at an upstream location (Hwy. 191) confirmed that trout existed at more than one location in this stream (M. G. Ryon, Environmental Sciences Division, Oak Ridge National Laboratory, personal observation). Rainbow trout were also observed in a small tributary on the western shore of Lloyds Lake.

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5. DISCUSSION

5.1 MONTEZUMA CREEK

Although it is generally well known that uranium mill tailings are potential sources of a number of trace metals to the environment, there has been very little recent study on the accumulation of metals in aquatic biota downstream of uranium mill tailing sites. Fish have been most often studied for bioaccumulation and/or assessment of uranium mill tailing effects. Parkhurst et al. (1984) found that instream bioaccumulation of uranium was very low in trout collected downstream of a uranium mining operation in Colorado, and the authors found no significant toxicity to resident aquatic biota. However, bioaccumulation studies of trace metals were not conducted. Some fish samples collected for metal accumulation near the Atlas Uranium Mill in Utah were found to contain elevated concentrations of arsenic, iron, lead, manganese, mercury, selenium, total uranium, and vanadium, and elevated activities of gross alpha, gross beta, lead-210, polonium-210, radium-226, and thorium-230 (U. S. Nuclear Regulatory Commission 1996). However, the sampling data was limited and only selenium and mercury appeared to exceed background concentrations by more than 2 or 3 fold.

Aquatic macroinvertebrates have been commonly used in recent years to evaluate metal bioaccumulation at other contaminated mining sites (other than uranium) throughout the Rocky Mountains (e.g. Cain et al. 1992; Kiffney and Clements 1993). In the absence of fish from Montezuma Creek, aquatic macroinvertebrates were collected for bioaccumulation evaluation in this study. Although there are special problems with using invertebrates for bioaccumulation studies, such as the necessity of using small sample sizes and multiple species, invertebrates can be advantageous as a monitoring tool because (1) they can accumulate high levels of metals, (2) they are relatively sedentary and represent exposure at the site of collection, and (3) as a food source they can provide a means of transferring metals to higher trophic levels

(Poulton et al. 1995).

In this study, aquatic macroinvertebrates appeared to be sensitive indicators of low-level metal contamination. Elevated concentrations of some contaminants such as arsenic, selenium, uranium, and vanadium, and elevated activities of gross alpha and gross beta in invertebrates from Montezuma Creek are consistent with the observed contamination in water at some stream locations near the mill site (Tables 2.4 and 5.1; Rust Geotech 1995a). Many of these metals, including arsenic and molybdenum, are well known by-products of uranium mill tailing operations (Eisler 1988a, 1988b). The spatial pattern of metal contamination in Montezuma Creek invertebrates suggests that the mill tailing site is a likely source of bioavailable metals to the creek. However, the differences among sites were often small, thus water quality (particularly alkalinity and hardness) and geohydrology factors cannot be ruled out as affecting metal bioavailability among Montezuma Creek sites. Future studies should include sampling of invertebrates upstream of the mill site as an additional reference site to evaluate natural instream metal contributions. Metal contamination in invertebrates did not appear to extend far downstream in Montezuma Creek; metal concentrations in invertebrates from the lowermost Montezuma Creek site (MZ-9) were at or near background. The exception was uranium, which was measurably elevated in invertebrates at the lowermost site in comparison to the reference stream values. In general, however, most of the significant metal contamination observed in Montezuma Creek invertebrates was localized within approximately 2.5 km of the mill tailing site.

Although metal concentrations are clearly elevated in Montezuma Creek invertebrates collected near the mill site, the levels are not excessive in comparison to common wildlife benchmarks, and most metal concentrations are within or near a range of values observed in uncontaminated streams in other regions (Table 5.1; Lynch et al 1988; Poulton et al. 1995; Eisler 1988a, 1988b, 1988c). The dietary benchmarks for the northern rough-winged swallow is provided in Table 5.1 for comparison purposes [from Opresko et al. (1996)]. Only aluminum, selenium and zinc at some Montezuma Creek locations exceeded the No Observed

Table 5.1. Mean metal concentrations (µg/g, wet wt.) in aquatic macroinvertebrates from Montezuma Creek in comparison to reference sites and other reported values.

	Montezuma Creek sites[a]				Comparison Values			Reference sites[b]			
Analyte	MZ-2	MZ- 3	MZ-5	MZ-9	Req. Det. Limit[c]	BCF[d] (Montezuma Cr.)	Dietary Benchmark[e]	Verdure Creek	First Creek	Red River	Rock Creek
Al	575.27	565.01	939.60	862.41	40.0	-	145.35	559.88	396.11	-	166
As	0.70	0.91	0.54	0.62	1.0	122 - 607	6.80	<0.55	<0.31	0.18	0.54
Be	<0.04	<0.04	<0.04	<0.06	-	-	-	<0.06	0.06	-	-
Cd	<0.04	<0.04	<0.04	<0.06	-	-	1.92	<0.06	0.12	0.38	0.03
Cr	0.52	0.68	0.65	0.68	-	-	1.33	0.60	0.82	0.98	-
Co	0.63	0.40	0.69	0.38	5.0	-	-	0.49	0.45	-	-
Cu	2.67	2.40	2.71	4.90	10.0	662	62.28	3.33	2.88	8.6	5.2
Pb	0.41	0.36	0.49	0.41	-	-	5.10	0.26	0.43	0.1	0.11
Mo	0.63	0.45	0.33	0.24	10.0	-	4.64	0.27	0.07	0.56	-
Ni	0.96	1.08	1.23	0.67	-	-	102.56	0.60	1.11	1.42	-
Se	1.41	1.09	0.94	<1.11	1.0	363 - 613	0.66	<1.10	<0.60	0.18	-
Sn	0.08	0.07	0.12	0.33	2.0	-	9.01	0.11	0.04	0.98	-
U	0.50	0.46	0.63	0.36	-	2 - 3	21.20	<0.06	0.16	-	-
V	5.44	7.28	5.78	5.01	5.0	555 - 659	15.11	4.41	2.80	-	-
Zn	22.11	16.74	18.07	22.07	10.0	-	19.21	26.21	14.15	64	42.4

[a] MZ = Montezuma Creek followed by the biological study area number. #2 represents the most upstream site and #9 the most downstream site.

[b] Mean aquatic macroinvertebrate concentrations in Verdure Creek, Utah; First Creek, Tennessee; the Red River, New Mexico (Lynch et al. 1988); and Rock Creek, Montana (Poultan et al. 1995). Red River and Rock Creek values are estimated wet wt. concentrations assuming 80% moisture in samples. Multiply by 5 to obtain dry wt. concentrations reported in the literature.

[c] Requested detection limit in Table 6-9 of the Remedial Investigation/Feasibility Plan, 1995.

[d] Estimated Bioconcentration Factors (BCF). The range across sites of observed BCFs for each metal where aqueous concentrations were available (Table 2.4) is provided.

[e] Dietary No Observed Adverse Effect Level (NOAEL) for northern rough-winged swallow according to Opresko et al. 1996.

Adverse Effect Level (NOAEL) (the cited benchmarks refer to concentrations in the diet below those which should not result in adverse effects). Although aluminum and zinc concentrations in Montezuma Creek invertebrates exceeded the benchmarks, they were not substantially higher than uncontaminated sites (Table 5.1; Lynch et al 1988; Poulton et al. 1995). Aluminum is a major constituent of inorganic sediments, and concentrations in invertebrates probably reflect the presence of this metal in the gut and on the exterior of the organisms. Selenium appeared to be the only metal in Montezuma Creek invertebrates that both exceeded the cited dietary benchmark and was also higher than reference stream invertebrates (Table 5.1). The maximum selenium concentration in Montezuma Creek invertebrates was still lower, however, than some background concentrations that have been reported for other biota that have a propensity for selenium accumulation (e.g., mussels, clams; Eisler 1988c). A detailed ecological risk assessment where other receptors and endpoints are evaluated would be needed to sufficiently assess the potential effects of low-level metal contamination in invertebrates on wildlife or other biota associated with Montezuma Creek. Obviously the level of concern is dependent on the acceptability of the assumptions used in the risk analysis. Overall, metal contamination in Montezuma Creek invertebrates appears to be relatively low in comparison to values reported in other field studies.

Bioconcentration factors (BCFs - the ratio of metal concentration in invertebrates to the concentration in water) were estimated for some metals using the mean aqueous concentrations given in Table 2.4. Many aqueous concentrations were below the detection limit and so BCFs were not calculated for these metals. In general, BCFs ranged from 120 to 660 for arsenic, copper, selenium, and vanadium (Table 5.1). The presence of higher concentrations of these metals in aquatic macroinvertebrates in comparison to levels in water would be expected, and demonstrates the usefulness of a biological integrator of contamination over time. However, not all contaminant concentrations are substantially elevated in invertebrates over concentrations in water. Invertebrates appeared to exhibit little overall bioconcentration of gross alpha activity relative to activity in the water of Montezuma Creek. Gross alpha activity in water below the mill site was typically 100 -200 pCi/L in 1994 (Rust Geotech 1995a). If invertebrate alpha activity is converted to a wet weight basis by dividing by 5 (an estimate based on % moisture in invertebrate samples), gross alpha activity of about 1.1 pCi/g wet wt. in invertebrates divided by the aqueous concentrations yields a BCF in the range 5 - 10. The estimated BCF for uranium in Montezuma Creek invertebrates was 2 - 3, based on the aqueous uranium concentrations from Table 2.4. Bioconcentration factors of less than 10 are typical for uranium (NCRP 1984), which constitutes most of the alpha activity in the creek water. However, since uranium only accounts for less than half (37%) of the alpha activity in invertebrates, other radioisotopes with higher BCFs must account for the remainder. Radium exhibits BCFs of 500 - 1000 in invertebrates (NCRP 1984) and occurs at concentrations of 0.5 - 1 pCi/L in Montezuma Creek (Rust Geotech 1995a). Thus, Ra-226 was a likely candidate for accounting for the 0.5 pCi/g wet wt. of gross alpha activity in invertebrates that was not explained by their uranium content.

Neither gross alpha nor gross beta activity demonstrated substantial bioaccumulation in aquatic invertebrates in Montezuma Creek, although the presence of elevated radionuclide activity in water was reflected by elevated alpha and beta activity in organisms. Internal radiation dose to invertebrates from accumulated gross alpha and beta activity would be 4 -8 mrad/day, well below levels harmful to aquatic life (U. S. Nuclear Regulatory Commission 1996).

Some natural changes and differences in macroinvertebrate community composition and structure would be anticipated with distance from the headwaters of a stream and changes in elevation (Clements and Kiffney 1995; Vannote et al. 1980). Crist and Trinca (1988) observed a sharp increase in densities downstream of the mill site. They hypothesized that it may have been associated with increased habitat availability and diversity, characteristics that would be expected with an increase in stream size and distance from the headwaters (Vannote et al. 1980). However, Crist and Trinca did find that the majority of the organisms collected at all sites were those considered to be fairly pollution-tolerant. Although changes in habitat may have contributed to some differences between the reference sites and those sites downstream of the mill site, several of the macroinvertebrate community characteristics observed downstream of the mill site in this study and the study of Crist and Trinca were indicative of one or more types of perturbations, and some recovery with increasing distance from the mill site. The mill site is a source of contamination as the bioaccumulation, sediment contaminant, and water quality data indicated, but other land use factors could have also contributed to some of the observed ecological differences. These factors include crop farming on the mesa on the south border of the stream, live stock grazing along much of the stream south of Hwy. 191, the location of a golf course just upstream of the mill site, a reservoir upstream of the mill site, and urbanization to the north. The high total densities in combination with a shift in numerical dominance from taxa such as the Oligochaeta and *Physella* just downstream of the mill site to taxa such as the mayfly *Baetis* much further away, are spatial changes often observed with increasing distance from a source of excess quantities of organic matter and nutrients (e.g., Hynes 1974; Wiederholm 1984). However, taxonomic richness is also generally reduced in the presence of enriched conditions (Wiederholm 1984), and this characteristic was not observed downstream of the mill site. Others have reported seeing not detectable effects on total richness at metal-contaminated sites (Clements 1991; Clements et al. 1988; Wiederholm 1984). A similar response for EPT richness has also been reported when metal concentrations are low to moderate (Kiffney and Clements 1994). Because EPT richness at those sites downstream of the mill site differed from only one reference site, it could not be definitively determined if EPT richness fell outside of the normal range for the surrounding area.

Stoneflies are typically intolerant of nutrient enrichment while being much more tolerant of metals (Hilsenhoff 1987; Lenat 1993; Clements 1991). If metals were the sole contaminants in Montezuma Creek, stoneflies would be expected at at least some sites since mayflies, which are generally more intolerant of metals (Clements 1991), occurred at all sites. However, the low densities of stoneflies at the reference sites imply that they may be naturally rare in these streams at this time of the year, and thus could have easily been missed with the collection of only three replicates per site.

Mayflies are one of the most sensitive groups of insects to metals while generally being more tolerant of enrichment (Clements 1991; Hilsenhoff 1987; Lenat 1993). Mayflies in the family Heptageniidae are reportedly very sensitive to metals, while some species of *Baetis* appear to tolerate moderate concentrations (Clements 1994; Kiffney and Clements 1994b; Roline 1988). The response of the midge tribe, Tanytarsini has been observed to be very similar to that of *Baetis* (Clements 1994; Kiffney and Clements 1994; Roline 1988). *Baetis* has good dispersal abilities which allow it to sometimes be one of the first mayflies to recolonize an impacted stream (Mackay 1992). In a similar sized stream in Oak Ridge, Tennessee, which is thought to be primarily impacted by metals, *Baetis* has been found to be one of the first mayflies to recolonize as some recovery has occurred (Cada et al. 1995). In the current study, heptageniid mayflies were collected at the reference sites only, while *Baetis* and Tanytarsini were collected at all sites and was especially abundant at the two sites farthest from the mill site. In 1988, Crist and Trinca (1988) collected *Baetis* at all three of the study sites on Montezuma Creek, but heptageniids were only collected upstream of the mill site; however, they provided no information on the Tanytarsini. The only other mayfly taxon collected downstream of the mill site was *Callibaetis* at MZ-5, and the taxon was also collected by Crist and Trinca (1988) close to MZ-2 and MZ-3). Because this taxon is usually associated with non-flowing waters (Edmunds and Waltz 1996), its occurrence at this site may reflect this site's close proximity to numerous beaver ponds immediately upstream and downstream. The influence of the beaver ponds was also shown by the presence of a midge *(Chaoborus)* that typically occurs in standing waters (Webb and Brigham 1982).

The invertebrate bioaccumulation data and the limited available water quality and sediment contaminant data provided some supporting evidence for the hypothesis that the benthic macroinvertebrate community downstream of the mill site is responding to a combination of impacts associated with excess quantities of metals and nutrients. The facts that (1) nutrient concentrations (as expressed as nitrate + nitrite) upstream of the mill site at the reference site MZG are at least periodically as high as or higher than at some of the downstream sites, and (2) macroinvertebrate densities were lower, strongly imply that nutrients alone are not affecting Montezuma Creek downstream of the mill site. That is, reduction or elimination of these contaminant sensitive taxa in the presence of excess nutrients would allow the more tolerant taxa to proliferate because of an increased food supply. Proliferation would also be further aided by reductions in competition for the food and a possible reduction of predation. Without continuously monitoring metal concentrations at all study sites, it cannot be definitively stated that metals never exceed concentrations that are toxic to biota. However, the tendency for higher concentrations of some elements to occur in invertebrates at the sites nearest the mill site correspond with the generally poorer macroinvertebrate community that occurred closer to the mill site. If the limited water quality data available were representative of typical conditions, they only indicated slightly higher concentrations of some contaminants. However, it is possible that some contaminants, either alone or in combination, exist in concentrations that would be toxic to some of the most sensitive taxa.

The fish community surveys documented the absence of fish in Montezuma Creek below Lloyds Lake and above site MZ-9 in Montezuma Canyon. The missing fish community continues the pattern reported by Crist and Trinca (1988) in an earlier ecological analysis of Montezuma Creek. The absence of fish from Montezuma Creek is further supported by the presence of tiger salamander larvae in several beaver ponds. These salamanders normally reproduce only in bodies of water without fish (Behler and King 1979). The surveys of Montezuma Creek below Verdure Creek did establish that fish species could survive in this section. Similarly, the presence of rainbow trout in Verdure Creek suggests that some streams in this area of similar size and structure to Montezuma Creek above MZ-9 are quite capable of supporting a permanent fish community. The rainbow trout population in Verdure Creek compared quite favorably with other reported Utah stream populations. In August surveys of a similar stream in south central Utah (Platts and Nelson 1988), mean rainbow trout biomass for 5 years of sampling was 1.6 g/m^2 which was a third of the trout biomass measured in our survey.

The habitat analysis of Montezuma Creek suggested that an abundance of suitable habitat exists for fish. Habitat variables that have been identified as being of primary importance to rainbow trout include stream flow, maximum stream temperature, instream cover, pool depth, gradient, elevation, and substrate embeddedness (Binns and Eiserman 1979; Baltz et al. 1991; Nelson et al. 1992; Harvey 1993; Hubert and Kozel 1993). The QHEI ratings for many of these measures were positive and comparable to Verdure Creek which indicates that these specific variables should not be limiting the establishment of fish populations in Montezuma Creek.

The absence of speckled dace from sites further up in the system is puzzling. The dace occur in other western streams with elevation, gradient, and habitat (Minckley 1973; Moyle 1976) similar to Montezuma Creek. Also, the species, at least in Arizona, is described as being extremely tolerant of intermittent stream conditions (John 1964) and a strong recolonizing species (Pearsons et. al. 1992). These characteristics should allow them to successfully survive in Montezuma Creek above MZ-9 or at least reinvade during times of consistent flows. Further, associations of speckled dace and rainbow trout are reported from streams with similar physical characteristics as Montezuma Creek (Moyle 1976; Johnson 1985; Moyle and Baltz 1985; Moyle and Vondracek 1985).

Crist and Trinca (1988) speculated that low- and no-flow conditions prior to the completion of Lloyds Lake were likely to be responsible for the absence of any fish. Based on USGS data from a gauging station located near MZG (Table 2.3), the number of zero-flow days is highly variable, but generally less than 10% of the year during the last five years of available data. The low flows during late summer (CPF, Table 2.3) are also widely variable, but from 1988 through 1992 flows remained high enough to support limited trout biomass (Binns and Eiserman 1979). Much of the creek flow is still used for irrigation which could exacerbate the no-flow conditions during summer. A key factor in the impact of low flows is the role of the larger beaver ponds in Montezuma Creek and whether they would provide a sufficient quality refuge during periods when flow is reduced or absent.

Often the absence of fish from a stream reflects a limited or marginal food base (Binns and Eiserman 1979). Based on quantitative surveys of the benthic macroinvertebrate communities and observations of abundant periphyton, this possible explanation for the absence of fish in Montezuma Creek does not seem likely. Similarly, although levels of metals pose a risk to trout in some western streams (Pascoe et al. 1994; Farag et al. 1994), the water and sediment data for the Monticello Mill Site indicate that current conditions are probably not toxic enough to account for the absence of fish in Montezuma Creek, although the available data sets are not extensive enough to determine if toxic "spikes" ever occur. The bioaccumulation of toxic metals in invertebrates could serve as another route for toxic exposure of fish populations (Woodward et al. 1994). Although bioaccumulation data from our study showed that macroinvertebrates are exposed to and accumulate metals in Montezuma Creek, it does not appear likely that concentrations in invertebrates are high enough to have adverse effects on fish that eat them.

In describing the generally patchy distribution of desert fish, Smith (1981) states that barriers, either based on relief or aridity, play a major role in determining which species occupy or reinvade streams. The presence of a barrier to fish migration into upper Montezuma Creek was not confirmed during these surveys. However, falls and significant rapids have been observed in Montezuma Creek within the Montezuma Canyon sections which may act as barriers (N. E. Korte, ORNL, Grand Junction, Colorado, personal communication). Past conditions such as extended no-flow periods, deleterious water quality, or toxic concentrations of metals or other contaminants may have eliminated any fish populations during the previous operations of the Monticello Mill Site. After closure of the mill and as conditions improved in upper Montezuma Creek to the point where trout, dace, or other fish species could theoretically establish permanent populations, then a downstream barrier would prevent successful migration. Thus, the current absence of fish from upper Montezuma Creek could be an inaccurate reflection of the quality of the stream and its ability to actually support a fish community. Such a pattern was observed in a fly ash contaminated stream that had undergone remediation but was isolated by downstream barriers. The habitat, food base, and water quality had improved substantially enough, that a planned introduction of a native benthic fish species was successful in establishing a fish population in the isolated section (Carrico and Ryon 1996).

5.2 STOCK POND AND MZ-5 BEAVER POND - BENTHIC MACROINVERTEBRATES

The potential effects of the Monticello Mill Site on the macroinvertebrate communities in the Stock Pond and MZ-5 beaver pond on Montezuma Creek could only be generally assessed because sampling was limited to a single qualitative sample per site. A diverse community of macroinvertebrates was found in each pond and consisted of a mixture of those taxa that live primarily on the bottom (benthic), those that cling to living or dead vegetation, and those that generally stay suspended in the water column. About half of the taxa collected from each site were benthic which is where the effects of contaminants are often thought to be the greatest because of their tendency to accumulate in the fine sediment particles. Sixteen more taxa were collected from the MZ-5 beaver pond than the Stock Pond, but this was probably due to the larger size and greater diversity of habitat in the beaver pond. The Stock Pond was much shallower (~ 15 to 23 cm vs ~ 30 to 91 cm deep) and habitat was limited to algal mats on the surface of the substrate and an unidentified macrophyte. The beaver pond had considerable numbers of cattails and other macrophytes as well as numerous large pieces of woody debris and abundant quantities of algal mats on the substrate. Thus, although adverse effects from the mill site cannot be quantified or detected from this study, it can be concluded that if any adverse effects were occurring, they were not significant enough to limit the establishment of a diverse community of invertebrates in either pond.

6. CONCLUSIONS

This study demonstrated both the presence of contamination in macroinvertebrates and an impacted macroinvertebrate community in Montezuma Creek downstream of the Monticello Mill Site. Concentrations of nickel, lead, selenium, molybdenum, uranium, and vanadium were elevated above background in macroinvertebrates as were gross alpha and beta activities. However, contaminant concentrations were low, and except for uranium, contamination of invertebrates appeared to be primarily localized within about a 2.5 km reach downstream of the mill site. Successful remediation of the mill site should result in lower concentrations of mill-related contaminants in Montezuma Creek macroinvertebrates.

Impacts to the macroinvertebrate community were also greatest just downstream of the mill site with some recovery further downstream. The ability of the stream to support high densities of macroinvertebrates, the lack of a detectable effect on total taxonomic richness, and the presence of some inverterbrate taxa that are typically moderately tolerant to various types of pollutants indicated that any adverse effects associate with the mill site were moderate. Based on taxonomic composition and community structure, the invertebrate community appeared to be responding to nutrient enrichment and low concentrations of metals. Successful remediation should result in the appearance of more taxa that are intolerant of metal contamination. However, because land use practices in the watershed probably contribute significantly to nutrient loading to the stream the effects of enrichment will probably remain.

The current absence of fish from Montezuma Creek cannot clearly be tied to the presence of contaminants. Habitat and food (i.e., benthic macroinvertebrates) availability appeared to be suitable to support a fish community, but past conditions such as extended periods of no stream flow, poor water quality, or toxic concentrations of contaminants may have eliminated fish and prevented recolonization. If historical populations of fish existed, recolonization could possibly be inhibited by the presence of barriers to upstream migration.

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Appendix A

QA RESULTS FOR THE BIOACCUMULATION TASK

APPENDIX A
QA RESULTS FOR THE BIOACCUMULATION TASK

Quality assurance was maintained by using replicate samples at each site, analysis of aquatic macroinvertebrates from reference areas (Verdure Creek in Utah and First Creek in east Tennessee), and determination of recoveries of analyte spikes. Quality assurance results are provided in appendix tables A.1-A.3. The recovery of spiked quantities of metals was good; the mean spike recovery for all metal analytes was 96%. Spike recoveries for aluminum and vanadium were not calculated due to the high concentrations of these analytes already present in the samples. The relatively low recovery of zinc (68%) was also likely due to the high levels already in the sample. The degree of analytical variation between replicate samples at the same site was low in most cases; when data from all sites were combined eleven of fourteen metals had mean coefficients of variation (CV) at 15% or less. No CV was calculated for beryllium because all results were below the level of detection. The CV for arsenic at MZ-9 (40%) was high because one sample was below the detection limit. The reason for the large difference in tin values at MZ-9 is unknown.

Radiochemistry spike recoveries and replicate results are shown in Table A.3. Percent recovery for alpha and beta activity were 91.6% and 110.6%, respectively. Replicate analysis for alpha and beta activity showed results of 5.95 pCi/g and 13.7 pCi/g, respectively, compared to the original results of 6.27 pCi/g and 20.8 pCi/g, respectively. Percent differences for alpha and beta activity were 5.1% and 34.1%.

Table A.1. Coefficients of variation (%) for metal concentrations among macroinvertebrate samples collected from each Montezuma Creek and Verdure Creek site.

	Metal														
Site[a]	Al	As	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Sn	U	V	Zn
MZ-2	8	28	ND[c]	ND	18	38	4	16	6	26	17	17	9	15	12
MZ-3	10	17	ND	ND	27	29	10	8	21	24	9	9	10	3	5
MZ-9	16	40[c]	ND	ND	2	9	3	17	0	10	ND	110	19	13	4
VD-1	3	ND	ND	10	11	10	10	16	6	0	ND	6	ND	11	0
Mean	9	28	ND	10	15	22	7	14	8	15	13	36	13	11	5

[a] MZ = Montezuma Creek followed by the biological study area number. VD = Verdure Creek followed by the biological study area number.
[b]ND = All results were below the level of detection and the coefficient of variation was not determined.
[c]One result was below the level of detection. The detection limit value was used to determine the coefficient of variation.

Table A.2. Metal spike recovery results.

Metal	Spike Amount[a]	Amount Recovered[a]	Percent Recovery
Aluminum	NA[b]	NA	NA
Arsenic	100	97	97
Beryllium	100	96	96
Cadmium	100	104	104
Chromium	100	94	94
Cobalt	100	94	94
Copper	100	94	94
Lead	100	106	106
Molybdenum	100	103	103
Nickel	100	92	92
Selenium	100	92	92
Tin	100	104	104
Uranium	100	107	107
Vanadium	NA	NA	NA
Zinc	100	68	68

[a]Concentrations are in µg/L.

[b]Spike recovery was not required for these analytes due to the high concentrations in the samples.

Table A.3. Radiochemistry spike recovery and replicate results for select aquatic macroinvertebrate samples.

	Spike Recovery			
Sample[a]	Analysis	Spike Amount[b]	Amount Recovered[b]	Percent Recovery
MZ-2 C	Alpha Activity	20.21	18.5	91.6
	Beta Activity	129.17	142.81	110.6

	Replicate results			
Sample[a]	Analysis	Original Results[b]	Replicate Results[b]	Percent Difference
MZ-2 B	Alpha Activity	6.27	5.95	5.1
	Beta Activity	20.8	13.7	34.1

[a]MZ-2 = Montezuma Creek biological study area #2 followed by the sample designation letter.
[b]Activity levels reported in pCi/g.

Appendix B

CONCENTRATIONS OF METALS AND RADIOCHEMISTRY RESULTS IN AQUATIC MACROINVERTEBRATES FROM MONTEZUMA AND VERDURE CREEKS, UTAH
AUGUST 1995

Table B.1. Summary of collection information and analytical results (µg/g, dry wt.) for aquatic macroinvertebrates collected from Montezuma Creek and Verdure Creek in Utah and First Creek in Tennessee.

Sample[a]	Species Comp. (% by Wt.)[b]	Collection Date	% Moist.[c]	Metal[d] Al	As	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Sn	U	V	Zn
MZ-2 A	Hy (11) Li (22) Ar (22) Ti (45)	8/17/95	82.1	3400	5.3	<0.22	<0.22	3.2	4.8	15.0	2.6	3.6	6.6	9.2	0.39	2.7	26.0	140.0
MZ-2 B	Hy (11) Li (22) Ar (22) Ti (45)	8/17/95	82.5	3500	3.4	<0.22	<0.22	3.4	3.9	16.0	2.5	3.4	5.9	8.4	0.47	2.8	33.0	130.0
MZ-2 C	Hy (11) Li (22) Ar (22) Ti (45)	8/17/95	83.1	3000	3.3	<0.21	<0.21	2.4	2.1	15.0	1.9	3.8	3.9	6.6	0.55	3.2	35.0	110.0
MZ-3 A	Hy (1) Li (6.5) Ar (17.5) Ti (75)	8/17/95	84.1	3900	5.5	<0.22	<0.22	3.7	2.9	15.0	2.2	3.4	6.1	6.2	0.49	3.2	48.0	110.0
MZ-3 B	Hy (1) Li (4) Ar (24) Ti (71)	8/17/95	84.0	3200	5.0	<0.22	<0.22	3.6	1.7	14.0	2.2	2.2	5.8	7.2	0.41	2.6	46.0	100.0
MZ-3 C	Hy (<1) Li (<1) Ar (20) Ti (80)	8/17/95	84.7	3700	6.9	<0.24	<0.24	5.7	3.0	17.0	2.5	3.0	8.8	7.4	0.48	3.0	45.0	110.0
MZ-5 A	Ar, Si (3) Ti (97)	8/17/95	81.9	5200	3.0	<0.23	<0.23	3.6	3.8	15.0	2.7	1.8	6.8	5.2	0.65	3.5	32.0	100.0
MZ-9 A	Hy, Am, Be (16) Li (41) Ar (23) Ti (20)	8/17/95	75.4	4000	<2.3	<0.23	<0.23	2.8	1.7	21.0	1.9	1.0	3.0	<4.5	2.4	1.7	19.0	90.0
MZ-9 B	Hy, Am, Be (<1) Li (40) Ar (22) Ti (38)	8/17/95	76.8	3200	4.1	<0.23	<0.23	2.9	1.5	20.0	1.5	1.0	2.6	<4.7	0.30	1.3	23.0	95.0
VD-1 A	Hy, Pe (11) Li (21) Ar (68)	8/17/95	76.3	2300	<2.1	<0.21	0.38	2.3	1.9	15.0	0.96	1.2	2.5	<4.3	0.47	<0.21	17.0	110.0

Table B.1 (Continued)

Sample[a]	Species Comp. (% by Wt.)[b]	Collection Date	% Moist.[c]	Metal[d] Al	As	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Sn	U	V	Zn
VD-1 B	Hy, Pe (22) Li (21) Ar (57)	8/17/95	76.1	2400	<2.3	<0.23	0.33	2.7	2.2	13.0	1.2	1.1	2.5	<4.6	0.43	<0.23	20.0	110.0
FC 1 A	Ti (77) Ep, Pl (23) Ol (<1)	2/21/96	87.0	4000	<2.3	0.51	0.87	5.4	3.7	20.0	3.7	0.57	8.9	<4.5	0.28	1.5	22.0	110.0
FC 1 B	Ti (77) Ep, Pl (22) Ol (<1)	2/21/96	87.2	2200	<2.4	0.33	0.75	3.6	2.8	24.0	2.3	0.49	7.3	<4.7	<0.24	1.0	17.0	99.0
FC 1 C	Ti (77) Ep, Pl (22) Ol (<1)	2/21/96	87.0	3000	<2.3	0.50	1.10	10.0	3.9	23.0	3.9	0.68	9.6	<4.6	0.40	1.2	26.0	120.0

[a] MZ = Montezuma Creek followed by the biological study area number and the sample ID letter. #2 represents the most upstream area and #9 the most downstream area. VD-1 = Verdure Creek biological study area number 1 followed by the sample ID letter. FC 1 = First Creek biological study area #1 followed by the sample ID letter.

[b] Taxonomic groups: Hy = Hydropsychidae, Li = Limnophilidae, Ar = *Argia* sp., Ti = Tipulidae, Si = Simuliidae, Am = Amphipoda, Be = Dytiscidae beetle, Ep = Ephemeroptera, Pl = Plecoptera, Ol = Oligochaeta. In parenthesis after each taxon is the estimated % by weight of that group within the total sample.

[c] Percent moisture = 100 * [1 - (Dry Wt./Wet Wt.)]

[d] Metal concentrations (μg/g) for dry wt. samples. Less than (<) indicates that the concentration was below the level of detection and that a dilution was performed to achieve optimal matrix for analysis.

Table B.2. Mean metal concentrations in aquatic macroinvertebrate samples (µg/g, dry wt., ± SE) from Montezuma Creek and Verdure Creek, Monticello, Utah, 1995.

	Site[a]				
Metal	MZ-2[b]	MZ-3[b]	MZ-5[c]	MZ-9[d]	VD-1[d]
Aluminum	3300 ± 153	3600 ± 208	5200	3600 ± 400	2350 ± 50
Arsenic	4.00 ± 0.65	5.80 ± 0.65	3.00	2.63 ± 1.48[e]	1.10 ± 0.05
Beryllium[f]	<0.22 ± 0.003	<0.23 ± 0.007	<0.23	<0.23 ± 0.00	<0.22 ± 0.01
Cadmium[f]	<0.22 ± 0.003	<0.23 ± 0.007	<0.23	<0.23 ± 0.00	0.36 ± 0.03
Chromium	3.00 ± 0.31	4.33 ± 0.68	3.60	2.85 ± 0.05	2.50 ± 0.20
Cobalt	3.60 ± 0.79	2.53 ± 0.42	3.80	1.60 ± 0.10	2.05 ± 0.15
Copper	15.33 ±0.33	15.33 ± 0.88	15.00	20.50 ± 0.50	14.00 ± 1.00
Lead	2.33 ± 0.22	2.30 ± 0.10	2.70	1.70 ± 0.20	1.08 ± 0.12
Molybdenum	3.60 ± 0.12	2.87 ± 0.35	1.80	1.00 ± 0.00	1.15 ± 0.05
Nickel	5.47 ± 0.81	6.90 ± 0.95	6.80	2.80 ± 0.20	2.50 ± 0.00
Selenium[f]	8.07 ± 0.77	6.93 ± 0.37	5.20	<4.60 ± 0.10	<4.45 ± 0.15
Tin	0.47 ± 0.05	0.46 ± 0.03	0.65	1.35 ± 1.05	0.45 ± 0.02
Uranium[f]	2.90 ± 0.15	2.93 ± 0.18	3.50	1.50 ± 0.20	<0.22 ● 0.01
Vanadium[f]	31.33 ± 2.73	46.33 ± 0.88	32.00	21.00 ± 2.00	18.50 ± 1.50
Zinc	126.67 ± 8.82	106.67 ± 3.33	100.00	92.50 ± 2.50	110.00 ± 0.00

[a]MZ = Montezuma Creek followed by the biological study are number. #2 represents the most upstream site and #9 the most downstream site. VD-1 = Verdure Creek biological study area #1. This is the reference site.

[b]N = 3

[c]N = 1

[d]N = 2

[e]One sample less was less than the detection limit. Half the detection limit was used to determine the SE.

[F] Where means are reported as less than the detection limit, all samples were reported as below the limit of detection. The detection limit value was used to determine the SE.

Table B.3. **Metal concentrations (µg/g, wet wt.) in aquatic macroinvertebrate samples in Montezuma Creek and two reference streams.**

	Analyte[a]														
Sample[b]	Al	As	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Sn	U	V	Zn
MZ-2 A	608.56	0.95	<0.04(d)	<0.04(d)	0.57	0.86	2.68	0.47	0.64	1.18	1.65	0.07	0.48	4.65	25.06
MZ-2 B	610.85	0.59	<0.04(d)	<0.04(d)	0.59	0.68	2.79	0.44	0.59	1.03	1.47	0.08	0.49	5.76	22.69
MZ-2 C	506.41	0.56	<0.04(d)	<0.04(d)	0.41	0.35	2.53	0.32	0.64	0.66	1.11	0.09	0.54	5.91	18.57
MZ-3 A	618.29	0.87	<0.03(d)	<0.03(d)	0.59	0.46	2.38	0.35	0.54	0.97	0.98	0.08	0.51	7.61	17.44
MZ-3 B	512.00	0.80	<0.04(d)	<0.04(d)	0.58	0.27	2.24	0.35	0.35	0.93	1.15	0.07	0.42	7.36	16.00
MZ-3 C	564.74	1.05	<0.04(d)	<0.04(d)	0.87	0.46	2.59	0.38	0.46	1.34	1.13	0.07	0.46	6.87	16.79
MZ-5 A	939.60	0.54	<0.04(d)	<0.04(d)	0.65	0.69	2.71	0.49	0.33	1.23	0.94	0.12	0.63	5.78	18.07
MZ-9 A	982.10	<0.57(d)	<0.06(d)	<0.06(d)	0.69	0.42	5.16	0.47	0.25	0.74	<1.11(d)	0.59	0.42	4.67	22.10
MZ-9 B	742.72	0.95	<0.05(d)	<0.05(d)	0.67	0.35	4.64	0.35	0.23	0.60	<1.09(d)	0.07	0.30	5.34	22.05
VD-1 A	545.99	<0.50(d)	<0.05(d)	<0.05(d)	0.55	0.45	3.56	0.23	0.28	0.59	<1.02(d)	0.11	<0.05(d)	4.04	26.11
VD-1 B	573.76	<0.55(d)	<0.06(d)	<0.06(d)	0.65	0.53	3.11	0.29	0.26	0.60	<1.10(d)	0.10	<0.06(d)	4.78	26.30
FC 1 A	518.13	<0.30(d)	0.07	0.11	0.70	0.48	2.59	0.48	0.07	1.15	<0.58(d)	0.04	0.19	2.85	14.25
FC 1 B	280.61	<0.31(d)	0.04	0.10	0.46	0.36	3.06	0.29	0.06	0.93	<0.60(d)	<0.03(d)	0.13	2.17	12.63
FC 1 C	389.61	<0.30(d)	0.06	0.14	1.30	0.51	2.99	0.51	0.09	1.25	<0.60(d)	0.05	0.16	3.38	15.58

[a](d) = Dilution performed to achieve optimal matrix for analysis.

[b]MZ = Montezuma Creek followed by the biological study area number. #2 represents the most upstream site and #9 the most downstream site. VD-1 = Verdure Creek biological study area #1. FC 1 = First Creek biological study area #1.

Table B-4. Gross alpha, gross beta, and isotope specific gamma activity (± limit of error) in aquatic macroinvertebrates collected from Montezuma and Verdure Creeks in Utah, and First Creek in Tennessee.

	Alpha	Beta	Gamma Activity[b]			
Sample[a]	Activity[b]	Activity[b]	Cs-137	Pa-234m	Th-234	U-235
MZ-2 A	5.23 ± 3.98	2.14 ± 8.8	-12.2 ± 23[c]	6640 ± 4200[f,g]	-136 ± 260[c,f]	17.2 ± 32[d]
MZ-2 B	6.27 ± 4.1	20.8 ± 8.9	-2.89 ± 11[c]	40.4 ± 2000[d,f]	157 ± 140[f,g]	-0.421 ± 11[c]
MZ-2 C	8.38 ± 4.3	14.1 ± 8.1	7.11 ± 21[d]	-1630 ± 4100[c,f]	62.0 ± 250[d,f]	25.7 ± 28[d]
MZ-3 A	6.14 ± 4.2	10.4 ± 8.2	-3.47 ± 11[c]	-567 ± 2000[c,f]	-46.5 ± 150[c,f]	1.83 ± 11[d]
MZ-3 B	4.39 ± 3.9	11.3 ± 8.4	0.103 ± 2.3[d]	302 ± 430[d,f]	-13.1 ± 27[c,f]	1.36 ± 3.3[d]
MZ-3 C	4.28 ± 4.1	18.1 ± 9.0	-0.138 ± 12[e]	1340 ± 2100[d,f]	46.7 ± 160[d,f]	8.31 ± 11[d]
MZ-5 A	5.51 ± 4.1	16.6 ± 8.7	4.20 ± 23[d]	1500 ± 4100[d,f]	-2.01 ± 270[c,f]	12.1 ± 33[d]
MZ-9 A	1.72 ± 3.5	8.81 ± 8.2	-5.58 ± 12[c]	450 ± 2000[d,f]	44.7 ± 150[d,f]	-2.28 ± 10[c]
MZ-9 B	-0.375 ± 3.1	11.7 ± 8.7	-11.4 ± 24[c]	2800 ± 4500[d,f]	-4.80 ± 280[c,f]	17.7 ± 34[d]
VD-1 A	-0.0194 ± 2.8	10.0 ± 8.0	-1.68 ± 11[c]	-270 ± 1900[c,f]	80.1 ± 140[d,f]	-1.47 ± 9.5[c]
VD-1 B	0.661 ± 3.2	13.7 ± 8.9	3.39 ± 24[d]	3930 ± 4300[d,f]	-65.4 ± 270[c,f]	21.6 ± 34[d]
FC 1 A	3.21 ± 3.9	12.8 ± 8.3	3.89 ± 11[d]	-384 ± 2000[c,f]	56.3 ± 150[d,f]	-1.86 ± 11[c]
FC 1 B	3.39 ± 4.1	14.8 ± 8.6	6.78 ± 23[d]	908 ± 4700[d,f]	-66.5 ± 280[c,f]	-
FC 1 C	6.25 ± 4.5	30.6 ± 9.1	-4.75 ± 12[c]	1730 ± 2000[d,f]	27.4 ± 150[d,f]	1.89 ± 11[d]

[a]MZ = Montezuma Creek followed by the biological study area number and the sample ID letter. #2 represents the most upstream site and #9 the most downstream site. VD-1 = Verdure Creek biological study area #1 followed by the sample ID letter. FC 1 = First Creek biological study area #1 followed by the sample ID letter.

[b]Activity is measured as pCi/g.

[c]Result is less than background.

[d]Result of analysis is less than the minimal detectable activity, confidence level is less than 95%.

[e]Gamma photopeak near minimal detectable activity resulting in a poor curve fit.

[f]Daughter of uranium isotopes. Reported for comparison purposes only.

[g]Tentatively identified isotope.

Appendic C

CHECKLIST OF BENTHIC MACROINVERTEBRATES IN MONTEZUMA CREEK AND VERDURE CREEK

Table C.1. Checklist of benthic macroinvertebrates collected from Montezuma Creek, Verdure Creek, and the Stock Pond and Beaver Pond on Montezuma Creek, August 1995.

Taxon	Site[a,b]								
	MZG	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZ-5P	SP
Turbellaria									
Planariidae	0.4	-	-	-	-	-	-	-	-
Nemertea?	-	-	3.9	-	-	-	-	-	-
Nematomorpha	-	-	-	-	-	0.4	-	-	-
Nematoda	23.0	35.5	7.2	24.0	5.7	2.2	6.5	X	X
Annelida									
Hirudinea	-	-	-	0.4	-	-	-	-	-
Glossiphoniidae									
Helobdella stagnalis	-	-	-	-	-	-	-	-	X
Oligochaeta	80.4	2836.4	687.1	544.3	23.7	82.2	38.4	X	X
Crustacea									
Amphipoda									
Talitridae									
Hyalella azteca	1.4	4.7	3.2	14.0	39.5	20.1	0.4	X	X
Hydracarina	-	-	0.4	-	-	-	-	X	-
Insecta									
Ephemeroptera									
Ameletidae									
Ameletus	0.4	-	-	-	-	-	-	-	-
Baetidae									
Baetis	366.3	258.7	925.7	601.4	2056.7	2835.3	477.6	X	X
Callibaetis	-	-	-	2.2	-	-	0.4	X	X
Centroptilum	-	-	-	-	-	-	0.4	-	-
Heptageniidae	0.4	-	-	-	-	-	-	-	-
Nixe	2.5	-	-	-	-	-	7.9	-	-

Table C.1. (Continued)

Taxon	Site[a,b]								
	MZG	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZ-5P	SP
Ephemeroptera (continued)									
Leptophlebiidae									
Paraleptophlebia	-	-	-	-	-	-	2.5	-	-
Odonata									
Zygoptera									
Coenagrionidae	-	-	-	-	-	-	-	X	-
Argia	-	1.8	1.1	5.4	2.9	2.2	4.3	-	-
Coenagrion/Enallagma	-	-	-	-	-	-	-	X	-
Ischnura	-	-	-	-	-	-	-	X	-
Lestidae									
Lestes	-	-	-	-	-	-	-	X	-
Anisoptera									
Aeshnidae									
Aeshna	-	-	-	-	-	-	-	X	X
Libellulidae									
Micrathyria	-	-	-	-	-	-	-	-	X
Plecoptera									
Capniidae	-	-	-	-	-	-	0.7	-	-
Cholorperlidae									
Sweltsa	0.7	-	-	-	-	-	1.4	-	-
Nemouridae									
Zapada	-	-	-	-	-	-	0.4	-	-
Perlodidae									
Isogenoides	-	-	-	-	-	-	1.4	-	-

Table C.1. (Continued)

Taxon	Site[a,b]								
	MZG	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZ-5P	SP
Hemiptera									
Corixidae	-	-	-	2.2	-	-	-	X	-
Cenocorixa	-	-	-	0.4	-	-	-	-	-
Cenocorixa bifida	-	-	-	-	-	-	-	X	X
Cenocorixa utahensis	-	-	-	-	-	-	-	X	X
Corisella inscripta	-	-	-	-	-	-	-	-	X
Corisella tarsalis	-	-	-	-	-	-	-	-	X
Hesperocorixa laevigata	-	-	-	-	-	-	-	X	X
Gerridae									
Gerris	-	-	-	-	-	-	-	X	-
Notonectidae	-	-	-	-	-	-	-	X	-
Notonecta	-	-	-	-	-	-	-	X	X
Trichoptera									
Hydropsychidae	-	-	-	-	-	-	0.4	X	X
Hydropsyche	17.2	26.6	27.6	7.5	14.7	56.3	89.0	-	-
Hydroptilidae	-	-	-	0.4	-	-	0.4	-	-
Hydroptila	1.1	781.1	95.1	166.5	335.5	530.0	68.9	X	-
Hydroptila?	-	-	-	-	-	-	0.7	-	-
Neotrichia	-	0.4	-	-	-	-	-	-	-
Ochrotrichia	3.6	305.7	8.6	17.9	58.1	55.6	2.5	-	-
Oxyethira	-	0.4	-	-	-	-	-	-	-
Leptoceridae	-	-	-	3.9	-	-	-	-	-
Limnephilidae	0.4	-	-	-	-	-	-	-	-
Hesperophylax	-	4.3	0.4	0.4	-	-	0.7	-	-
Limnephilus	1.8	-	-	-	-	-	-	-	-

Table C.1. (Continued)

Taxon	Site[a,b]								
	MZG	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZ-5P	SP
Coleoptera									
Dryopidae									
Helichus	-	-	-	-	-	0.7	0.7	-	-
Dytiscidae	-	-	-	-	-	-	-	X	-
Agabetes	-	-	-	-	-	-	-	X	X
Agabinus	5.4	5.0	12.2	1.1	2.2	2.2	0.4	X	X
Agabus	-	6.5	2.9	-	-	0.4	-	X	-
Hydroporus	0.4	0.4	1.4	-	0.7	-	-	-	X
Hygrotus	-	-	-	-	-	-	-	X	X
Hygrotus/Hydroporus	-	-	-	-	-	0.4	-	-	-
Laccophilus	-	-	-	-	-	-	-	X	X
Liodessus?	-	-	-	-	-	-	-	-	X
Nebrioporus/Stictotarsus	-	0.4	-	0.4	-	-	0.4	X	X
Oreodytes	-	1.4	0.4	0.4	-	-	0.4	X	X
Rhantus	-	-	-	-	-	-	-	X	-
Elmidae									
Microcylloepus pusillus	-	-	-	-	-	1.8	-	-	-
Optioservus	238.2	2.5	0.7	2.2	358.5	71.4	5.0	X	X
Haliplidae	-								
Haliplus	-	2.5	-	1.8	0.4	2.9	-	X	X
Helophoridae									
Helophorus	-	-	-	-	0.4	0.7	-	X	X
Hydrophilidae									
Berosus	-	-	-	-	-	-	-	X	X
Cymbiodyta	-	-	-	-	-	-	-	-	X
Helochares?	-	-	-	0.4	-	-	-	-	-
Parachymus	-	-	-	-	-	-	-	X	-
Tropisternus	-	-	-	-	-	-	-	X	-

Table C.1. (Continued)

Taxon	Site[a,b]								
	MZG	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZ-5P	SP
Diptera									
Ceratopogonidae	8.3	102.3	53.1	59.6	28.7	16.1	10.4	X	X
Ceratopogonidae?	-	-	-	-	0.4	0.4	-	-	-
Chaoboridae									
Chaoborus	-	0.4	-	107.3	-	-	-	X	-
Chironomidae	1.8	28.0	31.9	188.0	27.6	63.9	8.6	X	X
Chironominae									
Chirnomini	2.5	11.5	7.5	19.4	0.7	2.2	10.0	X	X
Tanytarsini	23.3	99.4	29.1	407.6	81.4	550.4	26.9	X	X
Orthocladiinae	97.6	1802.7	1226.4	1686.4	198.4	1461.4	229.6	X	X
Prodiamesinae	0.4	-	-	-	-	-	-	-	X
Tanypodinae	24.8	61.0	62.1	90.8	45.2	329.4	42.0	X	X
Culicidae									
Culex	-	-	-	1.8	-	0.4	-	X	X
Culiseta	-	-	-	2.9	-	-	-	X	-
Cyclorrhaphous-Brachycera	-	-	-	-	-	-	-	X	-
Dixidae									
Dixa	1.4	0.4	-	-	-	2.5	-	-	-
Dixella	-	0.4	-	-	-	1.8	-	-	-
Empididae	-	1.4	-	1.1	0.4	4.3	-	-	-
Chelifera	5.4	16.5	14.0	27.6	2.9	15.8	3.6	-	-
Clinocera	-	0.4	-	-	-	-	-	-	-
Hemerodromia	-	-	-	0.4	2.2	17.9	-	-	-
Ephydridae	-	0.4	1.4	2.2	-	0.4	-	X	X
Muscidae									
Limnophora	-	3.2	6.1	2.5	-	7.5	-	-	-
Psychodidae									
Pericoma	-	-	-	-	-	0.4	-	-	-
Pericoma/Telmatoscopus	-	-	0.4	-	-	-	-	-	-

Table C.1. (Continued)

Taxon	Site[a,b]								
	MZG	MZ-2	MZ-3	MZ-5	MZ-6	MZ-9	VD-1	MZ-5P	SP
Diptera (continued)									
Simuliidae	0.4	-	-	-	-	-	-	-	-
Simulium	82.5	129.2	1602.1	3740.6	336.6	1990.0	41.1	X	-
Stratiomyidae									
Euparyphus	-	0.4	-	-	-	12.6	-	-	-
Tabanidae									
Tabanus	-	-	-	-	0.4	-	0.4	-	-
Tipulidae	-	-	-	-	-	-	0.4	-	-
Pseudolimnophila	0.4	-	-	-	-	-	-	-	-
Tipula	0.4	2.2	4.7	2.2	3.6	3.9	-	X	-
Mollusca									
Gastropoda									
Physidae									
Physella	2.5	113.9	158.2	21.2	59.9	28.3	4.7	X	X
Planorbidae	-	-	-	-	0.4	-	-	-	-
Gyraulus	-	0.4	-.4	-	-	0.7	-	-	-
Lymnaeidae	-	2.2	38.4	17.2	14	4.3	-	X	-
Bivalvia									
Sphaeriidae	-	1.8	-	-	-	3.2	-	X	-
Pisidium	0.4	4.7	1.1	92.6	7.9	10.0	-	X	X
Pisidium?	-	-	0.3	-	-	-	-	-	-
Sphaerium	1.4	1.8	2.2	-	-	1.1	-	-	-
Sphaerium?	-	2.5	1.8	15.8	2.2	7.5	-	-	-

[a]MZ = Montezuma Creek; VD = Verdure Creek; MZ-5P = Beaver Pond at MZ-5; SP = Stock Pond.

[b]Values associated with each taxon are means of three samples. A "-" indicates that the taxon was not collected or that the taxon was identified to a lower level at one or more sites; an "X" indicates a taxon's collection in a qualitative sample.

Appendix D

RAW QUANTITATIVE BENTHIC MACROINVERTEBRATE DATA FOR MONTEZUMA CREEK AND VERDURE CREEK

----------------------- STATION IDENTIFICATION=MZ2 -----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
1	AMP	HYALELLA AZTECA	1	8	12	95	1
2	CHI	CHIRONOMIDAE	1	8	12	95	19
3	CHI	CHIRONOMINI	1	8	12	95	9
4	CHI	ORTHOCLADIINAE	1	8	12	95	546
5	CHI	TANYPODINAE	1	8	12	95	46
6	CHI	TANYTARSINI	1	8	12	95	48
7	COL	AGABINUS SP	1	8	12	95	4
8	COL	AGABUS SP	1	8	12	95	3
9	COL	HALIPLUS SP	1	8	12	95	3
10	COL	HYDROPORUS SP	1	8	12	95	1
11	COL	NEBRIOPORUS/STICT	1	8	12	95	0
12	COL	OPTIOSERVUS SP	1	8	12	95	1
13	COL	OREODYTES SP	1	8	12	95	2
14	DIP	CERATOPOGONIDAE	1	8	12	95	123
15	DIP	CHAOBORUS SP	1	8	12	95	0
16	DIP	CHELIFERA SP	1	8	12	95	7
17	DIP	CLINOCERA SP	1	8	12	95	0
18	DIP	DIXA SP	1	8	12	95	0
19	DIP	DIXELLA SP	1	8	12	95	0
20	DIP	EMPIDIDAE	1	8	12	95	0
21	DIP	EPHYDRIDAE	1	8	12	95	0
22	DIP	EUPARYPHUS SP	1	8	12	95	1
23	DIP	LIMNOPHORA SP	1	8	12	95	4
24	DIP	SIMULIUM SP	1	8	12	95	129
25	DIP	TIPULA SP	1	8	12	95	1
26	EPH	BAETIS SP	1	8	12	95	242
27	GAS	GYRAULUS SP	1	8	12	95	1
28	GAS	LYMNAEIDAE	1	8	12	95	1
29	GAS	PHYSELLA SP	1	8	12	95	774
30	HYD	HYDRACARINA	1	8	12	95	7
31	NEM	NEMATA	1	8	12	95	42
32	ODO	ARGIA SP	1	8	12	95	0
33	OLI	OLIGOCHAETA	1	8	12	95	5240
34	PEL	PISIDIUM SP	1	8	12	95	1
35	PEL	SPHAERIIDAE	1	8	12	95	0
36	PEL	SPHAERIUM SP	1	8	12	95	5
37	PEL	SPHAERIUM?	1	8	12	95	0
38	TRI	HESPEROPHYLAX SP	1	8	12	95	4
39	TRI	HYDROPSYCHE SP	1	8	12	95	4
40	TRI	HYDROPTILA SP	1	8	12	95	619
41	TRI	NEOTRICHIA SP	1	8	12	95	0
42	TRI	OCHROTRICHIA SP	1	8	12	95	98
43	TRI	OXYETHIRA SP	1	8	12	95	0
44	AMP	HYALELLA AZTECA	2	8	12	95	9
45	CHI	CHIRONOMIDAE	2	8	12	95	15
46	CHI	CHIRONOMINI	2	8	12	95	12
47	CHI	ORTHOCLADIINAE	2	8	12	95	1850
48	CHI	TANYPODINAE	2	8	12	95	51
49	CHI	TANYTARSINI	2	8	12	95	126
50	COL	AGABINUS SP	2	8	12	95	3
51	COL	AGABUS SP	2	8	12	95	1

----------------------- STATION IDENTIFICATION=MZ2 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
52	COL	HALIPLUS SP	2	8	12	95	0
53	COL	HYDROPORUS SP	2	8	12	95	0
54	COL	NEBRIOPORUS/STICT	2	8	12	95	1
55	COL	OPTIOSERVUS SP	2	8	12	95	2
56	COL	OREODYTES SP	2	8	12	95	0
57	DIP	CERATOPOGONIDAE	2	8	12	95	99
58	DIP	CHAOBORUS SP	2	8	12	95	1
59	DIP	CHELIFERA SP	2	8	12	95	2
60	DIP	CLINOCERA SP	2	8	12	95	0
61	DIP	DIXA SP	2	8	12	95	0
62	DIP	DIXELLA SP	2	8	12	95	1
63	DIP	EMPIDIDAE	2	8	12	95	1
64	DIP	EPHYDRIDAE	2	8	12	95	0
65	DIP	EUPARYPHUS SP	2	8	12	95	0
66	DIP	LIMNOPHORA SP	2	8	12	95	5
67	DIP	SIMULIUM SP	2	8	12	95	130
68	DIP	TIPULA SP	2	8	12	95	3
69	EPH	BAETIS SP	2	8	12	95	222
70	GAS	GYRAULUS SP	2	8	12	95	0
71	GAS	LYMNAEIDAE	2	8	12	95	3
72	GAS	PHYSELLA SP	2	8	12	95	926
73	HYD	HYDRACARINA	2	8	12	95	40
74	NEM	NEMATA	2	8	12	95	47
75	ODO	ARGIA SP	2	8	12	95	1
76	OLI	OLIGOCHAETA	2	8	12	95	323
77	PEL	PISIDIUM SP	2	8	12	95	0
78	PEL	SPHAERIIDAE	2	8	12	95	5
79	PEL	SPHAERIUM SP	2	8	12	95	0
80	PEL	SPHAERIUM?	2	8	12	95	0
81	TRI	HESPEROPHYLAX SP	2	8	12	95	0
82	TRI	HYDROPSYCHE SP	2	8	12	95	53
83	TRI	HYDROPTILA SP	2	8	12	95	935
84	TRI	NEOTRICHIA SP	2	8	12	95	1
85	TRI	OCHROTRICHIA SP	2	8	12	95	364
86	TRI	OXYETHIRA SP	2	8	12	95	0
87	AMP	HYALELLA AZTECA	3	8	12	95	3
88	CHI	CHIRONOMIDAE	3	8	12	95	44
89	CHI	CHIRONOMINI	3	8	12	95	11
90	CHI	ORTHOCLADIINAE	3	8	12	95	2628
91	CHI	TANYPODINAE	3	8	12	95	73
92	CHI	TANYTARSINI	3	8	12	95	103
93	COL	AGABINUS SP	3	8	12	95	7
94	COL	AGABUS SP	3	8	12	95	14
95	COL	HALIPLUS SP	3	8	12	95	4
96	COL	HYDROPORUS SP	3	8	12	95	0
97	COL	NEBRIOPORUS/STICT	3	8	12	95	0
98	COL	OPTIOSERVUS SP	3	8	12	95	4
99	COL	OREODYTES SP	3	8	12	95	2
100	DIP	CERATOPOGONIDAE	3	8	12	95	63
101	DIP	CHAOBORUS SP	3	8	12	95	0

----------------------- STATION IDENTIFICATION=MZ2 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
102	DIP	CHELIFERA SP	3	8	12	95	37
103	DIP	CLINOCERA SP	3	8	12	95	1
104	DIP	DIXA SP	3	8	12	95	1
105	DIP	DIXELLA SP	3	8	12	95	0
106	DIP	EMPIDIDAE	3	8	12	95	3
107	DIP	EPHYDRIDAE	3	8	12	95	1
108	DIP	EUPARYPHUS SP	3	8	12	95	0
109	DIP	LIMNOPHORA SP	3	8	12	95	0
110	DIP	SIMULIUM SP	3	8	12	95	101
111	DIP	TIPULA SP	3	8	12	95	2
112	EPH	BAETIS SP	3	8	12	95	257
113	GAS	GYRAULUS SP	3	8	12	95	0
114	GAS	LYMNAEIDAE	3	8	12	95	2
115	GAS	PHYSELLA SP	3	8	12	95	1477
116	HYD	HYDRACARINA	3	8	12	95	41
117	NEM	NEMATA	3	8	12	95	10
118	ODO	ARGIA SP	3	8	12	95	4
119	OLI	OLIGOCHAETA	3	8	12	95	2342
120	PEL	PISIDIUM SP	3	8	12	95	12
121	PEL	SPHAERIIDAE	3	8	12	95	0
122	PEL	SPHAERIUM SP	3	8	12	95	0
123	PEL	SPHAERIUM?	3	8	12	95	7
124	TRI	HESPEROPHYLAX SP	3	8	12	95	8
125	TRI	HYDROPSYCHE SP	3	8	12	95	17
126	TRI	HYDROPTILA SP	3	8	12	95	623
127	TRI	NEOTRICHIA SP	3	8	12	95	0
128	TRI	OCHROTRICHIA SP	3	8	12	95	390
129	TRI	OXYETHIRA SP	3	8	12	95	1

----------------------- STATION IDENTIFICATION=MZ3 -----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
130	AMP	HYALELLA AZTECA	1	8	12	95	1
131	CHI	CHIRONOMIDAE	1	8	12	95	20
132	CHI	CHIRONOMINI	1	8	12	95	0
133	CHI	ORTHOCLADIINAE	1	8	12	95	601
134	CHI	TANYPODINAE	1	8	12	95	16
135	CHI	TANYTARSINI	1	8	12	95	6
136	COL	AGABINUS SP	1	8	12	95	9
137	COL	AGABUS SP	1	8	12	95	5
138	COL	HYDROPORUS SP	1	8	12	95	1
139	COL	OPTIOSERVUS SP	1	8	12	95	1
140	COL	OREODYTES SP	1	8	12	95	1
141	DIP	CERATOPOGONIDAE	1	8	12	95	28
142	DIP	CHELIFERA SP	1	8	12	95	9
143	DIP	EPHYDRIDAE	1	8	12	95	0
144	DIP	LIMNOPHORA SP	1	8	12	95	2
145	DIP	PERICOMA/TELMATOS	1	8	12	95	0

---------------------- STATION IDENTIFICATION=MZ3 ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
146	DIP	SIMULIUM SP	1	8	12	95	3277
147	DIP	TIPULA SP	1	8	12	95	2
148	EPH	BAETIS SP	1	8	12	95	852
149	GAS	GYRAULUS SP	1	8	12	95	0
150	GAS	LYMNAEIDAE	1	8	12	95	6
151	GAS	PHYSELLA SP	1	8	12	95	129
152	HYD	HYDRACARINA	1	8	12	95	75
153	NEM	NEMATA	1	8	12	95	3
154	NET	NEMERTEA?	1	8	12	95	0
155	ODO	ARGIA SP	1	8	12	95	1
156	OLI	OLIGOCHAETA	1	8	12	95	306
157	PEL	PISIDIUM SP	1	8	12	95	1
158	PEL	PISIDIUM?	1	8	12	95	0
159	PEL	SPHAERIUM SP	1	8	12	95	1
160	PEL	SPHAERIUM?	1	8	12	95	0
161	TRI	HESPEROPHYLAX SP	1	8	12	95	0
162	TRI	HYDROPSYCHE SP	1	8	12	95	20
163	TRI	HYDROPTILA SP	1	8	12	95	54
164	TRI	OCHROTRICHIA SP	1	8	12	95	7
165	AMP	HYALELLA AZTECA	2	8	12	95	7
166	CHI	CHIRONOMIDAE	2	8	12	95	50
167	CHI	CHIRONOMINI	2	8	12	95	8
168	CHI	ORTHOCLADIINAE	2	8	12	95	1977
169	CHI	TANYPODINAE	2	8	12	95	66
170	CHI	TANYTARSINI	2	8	12	95	33
171	COL	AGABINUS SP	2	8	12	95	19
172	COL	AGABUS SP	2	8	12	95	3
173	COL	HYDROPORUS SP	2	8	12	95	0
174	COL	OPTIOSERVUS SP	2	8	12	95	1
175	COL	OREODYTES SP	2	8	12	95	0
176	DIP	CERATOPOGONIDAE	2	8	12	95	86
177	DIP	CHELIFERA SP	2	8	12	95	24
178	DIP	EPHYDRIDAE	2	8	12	95	4
179	DIP	LIMNOPHORA SP	2	8	12	95	0
180	DIP	PERICOMA/TELMATOS	2	8	12	95	0
181	DIP	SIMULIUM SP	2	8	12	95	1103
182	DIP	TIPULA SP	2	8	12	95	3
183	EPH	BAETIS SP	2	8	12	95	1379
184	GAS	GYRAULUS SP	2	8	12	95	1
185	GAS	LYMNAEIDAE	2	8	12	95	52
186	GAS	PHYSELLA SP	2	8	12	95	159
187	HYD	HYDRACARINA	2	8	12	95	108
188	NEM	NEMATA	2	8	12	95	13
189	NET	NEMERTEA?	2	8	12	95	11
190	ODO	ARGIA SP	2	8	12	95	1
191	OLI	OLIGOCHAETA	2	8	12	95	989
192	PEL	PISIDIUM SP	2	8	12	95	0
193	PEL	PISIDIUM?	2	8	12	95	2
194	PEL	SPHAERIUM SP	2	8	12	95	3
195	PEL	SPHAERIUM?	2	8	12	95	5

---------------------- STATION IDENTIFICATION=MZ3 ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
196	TRI	HESPEROPHYLAX SP	2	8	12	95	1
197	TRI	HYDROPSYCHE SP	2	8	12	95	56
198	TRI	HYDROPTILA SP	2	8	12	95	83
199	TRI	OCHROTRICHIA SP	2	8	12	95	4
200	AMP	HYALELLA AZTECA	3	8	12	95	1
201	CHI	CHIRONOMIDAE	3	8	12	95	19
202	CHI	CHIRONOMINI	3	8	12	95	13
203	CHI	ORTHOCLADIINAE	3	8	12	95	840
204	CHI	TANYPODINAE	3	8	12	95	91
205	CHI	TANYTARSINI	3	8	12	95	42
206	COL	AGABINUS SP	3	8	12	95	6
207	COL	AGABUS SP	3	8	12	95	0
208	COL	HYDROPORUS SP	3	8	12	95	3
209	COL	OPTIOSERVUS SP	3	8	12	95	0
210	COL	OREODYTES SP	3	8	12	95	0
211	DIP	CERATOPOGONIDAE	3	8	12	95	34
212	DIP	CHELIFERA SP	3	8	12	95	6
213	DIP	EPHYDRIDAE	3	8	12	95	0
214	DIP	LIMNOPHORA SP	3	8	12	95	15
215	DIP	PERICOMA/TELMATOS	3	8	12	95	1
216	DIP	SIMULIUM SP	3	8	12	95	85
217	DIP	TIPULA SP	3	8	12	95	8
218	EPH	BAETIS SP	3	8	12	95	349
219	GAS	GYRAULUS SP	3	8	12	95	0
220	GAS	LYMNAEIDAE	3	8	12	95	49
221	GAS	PHYSELLA SP	3	8	12	95	153
222	HYD	HYDRACARINA	3	8	12	95	21
223	NEM	NEMATA	3	8	12	95	4
224	NET	NEMERTEA?	3	8	12	95	0
225	ODO	ARGIA SP	3	8	12	95	1
226	OLI	OLIGOCHAETA	3	8	12	95	620
227	PEL	PISIDIUM SP	3	8	12	95	2
228	PEL	PISIDIUM?	3	8	12	95	0
229	PEL	SPHAERIUM SP	3	8	12	95	2
230	PEL	SPHAERIUM?	3	8	12	95	0
231	TRI	HESPEROPHYLAX SP	3	8	12	95	0
232	TRI	HYDROPSYCHE SP	3	8	12	95	1
233	TRI	HYDROPTILA SP	3	8	12	95	128
234	TRI	OCHROTRICHIA SP	3	8	12	95	13

---------------------- STATION IDENTIFICATION=MZ5 ----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
235	AMP	HYALELLA AZTECA	1	8	12	95	25
236	CHI	CHIRONOMIDAE	1	8	12	95	172
237	CHI	CHIRONOMINI	1	8	12	95	40
238	CHI	ORTHOCLADIINAE	1	8	12	95	1737
239	CHI	TANYPODINAE	1	8	12	95	105

----------------------- STATION IDENTIFICATION=MZ5 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
240	CHI	TANYTARSINI	1	8	12	95	750
241	COL	AGABINUS SP	1	8	12	95	0
242	COL	HALIPLUS SP	1	8	12	95	1
243	COL	HELOCHARES?	1	8	12	95	0
244	COL	NEBRIOPORUS/STICT	1	8	12	95	0
245	COL	OPTIOSERVUS SP	1	8	12	95	1
246	COL	OREODYTES SP	1	8	12	95	0
247	DIP	CERATOPOGONIDAE	1	8	12	95	104
248	DIP	CHAOBORUS SP	1	8	12	95	62
249	DIP	CHELIFERA SP	1	8	12	95	24
250	DIP	CULEX SP	1	8	12	95	0
251	DIP	CULISETA SP	1	8	12	95	4
252	DIP	EMPIDIDAE	1	8	12	95	0
253	DIP	EPHYDRIDAE	1	8	12	95	0
254	DIP	HEMERODROMIA SP	1	8	12	95	1
255	DIP	LIMNOPHORA SP	1	8	12	95	0
256	DIP	SIMULIUM SP	1	8	12	95	1834
257	DIP	TIPULA SP	1	8	12	95	0
258	EPH	BAETIS SP	1	8	12	95	545
259	EPH	CALLIBAETIS SP	1	8	12	95	0
260	GAS	LYMNAEIDAE	1	8	12	95	37
261	GAS	PHYSELLA SP	1	8	12	95	42
262	HEM	CENOCORIXA SP	1	8	12	95	0
263	HEM	CORIXIDAE	1	8	12	95	0
264	HIR	HIRUDENIA	1	8	12	95	1
265	HYD	HYDRACARINA	1	8	12	95	18
266	NEM	NEMATA	1	8	12	95	30
267	ODO	ARGIA SP	1	8	12	95	3
268	OLI	OLIGOCHAETA	1	8	12	95	858
269	PEL	PISIDIUM SP	1	8	12	95	216
270	PEL	SPHAERIUM?	1	8	12	95	0
271	TRI	HESPEROPHYLAX SP	1	8	12	95	0
272	TRI	HYDROPSYCHE SP	1	8	12	95	1
273	TRI	HYDROPTILA SP	1	8	12	95	23
274	TRI	HYDROPTILIDAE	1	8	12	95	0
275	TRI	LEPTOCERIDAE	1	8	12	95	4
276	TRI	OCHROTRICHIA SP	1	8	12	95	25
277	AMP	HYALELLA AZTECA	2	8	12	95	12
278	CHI	CHIRONOMIDAE	2	8	12	95	206
279	CHI	CHIRONOMINI	2	8	12	95	10
280	CHI	ORTHOCLADIINAE	2	8	12	95	1694
281	CHI	TANYPODINAE	2	8	12	95	49
282	CHI	TANYTARSINI	2	8	12	95	348
283	COL	AGABINUS SP	2	8	12	95	1
284	COL	HALIPLUS SP	2	8	12	95	2
285	COL	HELOCHARES?	2	8	12	95	0
286	COL	NEBRIOPORUS/STICT	2	8	12	95	1
287	COL	OPTIOSERVUS SP	2	8	12	95	3
288	COL	OREODYTES SP	2	8	12	95	0
289	DIP	CERATOPOGONIDAE	2	8	12	95	44

---------------------- STATION IDENTIFICATION=MZ5 ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
290	DIP	CHAOBORUS SP	2	8	12	95	161
291	DIP	CHELIFERA SP	2	8	12	95	36
292	DIP	CULEX SP	2	8	12	95	2
293	DIP	CULISETA SP	2	8	12	95	4
294	DIP	EMPIDIDAE	2	8	12	95	2
295	DIP	EPHYDRIDAE	2	8	12	95	2
296	DIP	HEMERODROMIA SP	2	8	12	95	0
297	DIP	LIMNOPHORA SP	2	8	12	95	5
298	DIP	SIMULIUM SP	2	8	12	95	6189
299	DIP	TIPULA SP	2	8	12	95	4
300	EPH	BAETIS SP	2	8	12	95	563
301	EPH	CALLIBAETIS SP	2	8	12	95	6
302	GAS	LYMNAEIDAE	2	8	12	95	10
303	GAS	PHYSELLA SP	2	8	12	95	11
304	HEM	CENOCORIXA SP	2	8	12	95	1
305	HEM	CORIXIDAE	2	8	12	95	6
306	HIR	HIRUDENIA	2	8	12	95	0
307	HYD	HYDRACARINA	2	8	12	95	67
308	NEM	NEMATA	2	8	12	95	35
309	ODO	ARGIA SP	2	8	12	95	11
310	OLI	OLIGOCHAETA	2	8	12	95	454
311	PEL	PISIDIUM SP	2	8	12	95	41
312	PEL	SPHAERIUM?	2	8	12	95	42
313	TRI	HESPEROPHYLAX SP	2	8	12	95	1
314	TRI	HYDROPSYCHE SP	2	8	12	95	17
315	TRI	HYDROPTILA SP	2	8	12	95	92
316	TRI	HYDROPTILIDAE	2	8	12	95	1
317	TRI	LEPTOCERIDAE	2	8	12	95	1
318	TRI	OCHROTRICHIA SP	2	8	12	95	3
319	AMP	HYALELLA AZTECA	3	8	12	95	2
320	CHI	CHIRONOMIDAE	3	8	12	95	146
321	CHI	CHIRONOMINI	3	8	12	95	4
322	CHI	ORTHOCLADIINAE	3	8	12	95	1269
323	CHI	TANYPODINAE	3	8	12	95	99
324	CHI	TANYTARSINI	3	8	12	95	38
325	COL	AGABINUS SP	3	8	12	95	2
326	COL	HALIPLUS SP	3	8	12	95	2
327	COL	HELOCHARES?	3	8	12	95	1
328	COL	NEBRIOPORUS/STICT	3	8	12	95	0
329	COL	OPTIOSERVUS SP	3	8	12	95	2
330	COL	OREODYTES SP	3	8	12	95	1
331	DIP	CERATOPOGONIDAE	3	8	12	95	18
332	DIP	CHAOBORUS SP	3	8	12	95	76
333	DIP	CHELIFERA SP	3	8	12	95	17
334	DIP	CULEX SP	3	8	12	95	3
335	DIP	CULISETA SP	3	8	12	95	0
336	DIP	EMPIDIDAE	3	8	12	95	1
337	DIP	EPHYDRIDAE	3	8	12	95	4
338	DIP	HEMERODROMIA SP	3	8	12	95	0
339	DIP	LIMNOPHORA SP	3	8	12	95	2

----------------------- STATION IDENTIFICATION=MZ5 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
340	DIP	SIMULIUM SP	3	8	12	95	2402
341	DIP	TIPULA SP	3	8	12	95	2
342	EPH	BAETIS SP	3	8	12	95	568
343	EPH	CALLIBAETIS SP	3	8	12	95	0
344	GAS	LYMNAEIDAE	3	8	12	95	1
345	GAS	PHYSELLA SP	3	8	12	95	6
346	HEM	CENOCORIXA SP	3	8	12	95	0
347	HEM	CORIXIDAE	3	8	12	95	0
348	HIR	HIRUDENIA	3	8	12	95	0
349	HYD	HYDRACARINA	3	8	12	95	44
350	NEM	NEMATA	3	8	12	95	2
351	ODO	ARGIA SP	3	8	12	95	1
352	OLI	OLIGOCHAETA	3	8	12	95	205
353	PEL	PISIDIUM SP	3	8	12	95	1
354	PEL	SPHAERIUM?	3	8	12	95	2
355	TRI	HESPEROPHYLAX SP	3	8	12	95	0
356	TRI	HYDROPSYCHE SP	3	8	12	95	3
357	TRI	HYDROPTILA SP	3	8	12	95	349
358	TRI	HYDROPTILIDAE	3	8	12	95	0
359	TRI	LEPTOCERIDAE	3	8	12	95	6
360	TRI	OCHROTRICHIA SP	3	8	12	95	22

----------------------- STATION IDENTIFICATION=MZ6 -----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
361	AMP	HYALELLA AZTECA	1	8	12	95	7
362	CHI	CHIRONOMIDAE	1	8	12	95	2
363	CHI	CHIRONOMINI	1	8	12	95	0
364	CHI	ORTHOCLADIINAE	1	8	12	95	51
365	CHI	TANYPODINAE	1	8	12	95	9
366	CHI	TANYTARSINI	1	8	12	95	14
367	COL	AGABINUS SP	1	8	12	95	1
368	COL	HALIPLUS SP	1	8	12	95	0
369	COL	HELOPHORUS SP	1	8	12	95	0
370	COL	HYDROPORUS SP	1	8	12	95	0
371	COL	OPTIOSERVUS SP	1	8	12	95	129
372	DIP	CERATOPOGONIDAE	1	8	12	95	13
373	DIP	CERATOPOGONIDAE?	1	8	12	95	0
374	DIP	CHELIFERA SP	1	8	12	95	0
375	DIP	EMPIDIDAE	1	8	12	95	0
376	DIP	HEMERODROMIA SP	1	8	12	95	0
377	DIP	SIMULIUM SP	1	8	12	95	107
378	DIP	TABANUS SP	1	8	12	95	1
379	DIP	TIPULA SP	1	8	12	95	5
380	EPH	BAETIS SP	1	8	12	95	762
381	GAS	LYMNAEIDAE	1	8	12	95	3
382	GAS	PHYSELLA SP	1	8	12	95	18
383	GAS	PLANORBIDAE	1	8	12	95	0

---------------------- STATION IDENTIFICATION=MZ6 ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
384	HYD	HYDRACARINA	1	8	12	95	9
385	NEM	NEMATA	1	8	12	95	5
386	ODO	ARGIA SP	1	8	12	95	1
387	OLI	OLIGOCHAETA	1	8	12	95	23
388	PEL	PISIDIUM SP	1	8	12	95	6
389	PEL	SPHAERIUM?	1	8	12	95	0
390	TRI	HYDROPSYCHE SP	1	8	12	95	26
391	TRI	HYDROPTILA SP	1	8	12	95	86
392	TRI	OCHROTRICHIA SP	1	8	12	95	2
393	AMP	HYALELLA AZTECA	2	8	12	95	42
394	CHI	CHIRONOMIDAE	2	8	12	95	38
395	CHI	CHIRONOMINI	2	8	12	95	2
396	CHI	ORTHOCLADIINAE	2	8	12	95	144
397	CHI	TANYPODINAE	2	8	12	95	21
398	CHI	TANYTARSINI	2	8	12	95	39
399	COL	AGABINUS SP	2	8	12	95	0
400	COL	HALIPLUS SP	2	8	12	95	0
401	COL	HELOPHORUS SP	2	8	12	95	0
402	COL	HYDROPORUS SP	2	8	12	95	0
403	COL	OPTIOSERVUS SP	2	8	12	95	319
404	DIP	CERATOPOGONIDAE	2	8	12	95	40
405	DIP	CERATOPOGONIDAE?	2	8	12	95	0
406	DIP	CHELIFERA SP	2	8	12	95	1
407	DIP	EMPIDIDAE	2	8	12	95	0
408	DIP	HEMERODROMIA SP	2	8	12	95	2
409	DIP	SIMULIUM SP	2	8	12	95	195
410	DIP	TABANUS SP	2	8	12	95	0
411	DIP	TIPULA SP	2	8	12	95	2
412	EPH	BAETIS SP	2	8	12	95	1739
413	GAS	LYMNAEIDAE	2	8	12	95	10
414	GAS	PHYSELLA SP	2	8	12	95	50
415	GAS	PLANORBIDAE	2	8	12	95	1
416	HYD	HYDRACARINA	2	8	12	95	21
417	NEM	NEMATA	2	8	12	95	4
418	ODO	ARGIA SP	2	8	12	95	2
419	OLI	OLIGOCHAETA	2	8	12	95	22
420	PEL	PISIDIUM SP	2	8	12	95	8
421	PEL	SPHAERIUM?	2	8	12	95	0
422	TRI	HYDROPSYCHE SP	2	8	12	95	4
423	TRI	HYDROPTILA SP	2	8	12	95	280
424	TRI	OCHROTRICHIA SP	2	8	12	95	145
425	AMP	HYALELLA AZTECA	3	8	12	95	61
426	CHI	CHIRONOMIDAE	3	8	12	95	37
427	CHI	CHIRONOMINI	3	8	12	95	0
428	CHI	ORTHOCLADIINAE	3	8	12	95	358
429	CHI	TANYPODINAE	3	8	12	95	96
430	CHI	TANYTARSINI	3	8	12	95	174
431	COL	AGABINUS SP	3	8	12	95	5
432	COL	HALIPLUS SP	3	8	12	95	1
433	COL	HELOPHORUS SP	3	8	12	95	1

---------------------- STATION IDENTIFICATION=MZ6 ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
434	COL	HYDROPORUS SP	3	8	12	95	2
435	COL	OPTIOSERVUS SP	3	8	12	95	551
436	DIP	CERATOPOGONIDAE	3	8	12	95	27
437	DIP	CERATOPOGONIDAE?	3	8	12	95	1
438	DIP	CHELIFERA SP	3	8	12	95	7
439	DIP	EMPIDIDAE	3	8	12	95	1
440	DIP	HEMERODROMIA SP	3	8	12	95	4
441	DIP	SIMULIUM SP	3	8	12	95	636
442	DIP	TABANUS SP	3	8	12	95	0
443	DIP	TIPULA SP	3	8	12	95	3
444	EPH	BAETIS SP	3	8	12	95	3231
445	GAS	LYMNAEIDAE	3	8	12	95	26
446	GAS	PHYSELLA SP	3	8	12	95	99
447	GAS	PLANORBIDAE	3	8	12	95	0
448	HYD	HYDRACARINA	3	8	12	95	31
449	NEM	NEMATA	3	8	12	95	7
450	ODO	ARGIA SP	3	8	12	95	5
451	OLI	OLIGOCHAETA	3	8	12	95	21
452	PEL	PISIDIUM SP	3	8	12	95	8
453	PEL	SPHAERIUM?	3	8	12	95	6
454	TRI	HYDROPSYCHE SP	3	8	12	95	11
455	TRI	HYDROPTILA SP	3	8	12	95	569
456	TRI	OCHROTRICHIA SP	3	8	12	95	15

---------------------- STATION IDENTIFICATION=MZ9 ----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
457	AMP	HYALELLA AZTECA	1	8	12	95	25
458	CHI	CHIRONOMIDAE	1	8	12	95	47
459	CHI	CHIRONOMINI	1	8	12	95	0
460	CHI	ORTHOCLADIINAE	1	8	12	95	1231
461	CHI	TANYPODINAE	1	8	12	95	210
462	CHI	TANYTARSINI	1	8	12	95	243
463	COL	AGABINUS SP	1	8	12	95	1
464	COL	AGABUS SP	1	8	12	95	1
465	COL	HALIPLUS SP	1	8	12	95	3
466	COL	HELICHUS SP	1	8	12	95	0
467	COL	HELOPHORUS SP	1	8	12	95	0
468	COL	HYGROTUS/HYDROPOR	1	8	12	95	1
469	COL	MICROCYLLOEPUS PUSILLUS	1	8	12	95	2
470	COL	OPTIOSERVUS SP	1	8	12	95	69
471	DIP	CERATOPOGONIDAE	1	8	12	95	8
472	DIP	CERATOPOGONIDAE?	1	8	12	95	1
473	DIP	CHELIFERA SP	1	8	12	95	30
474	DIP	CULEX SP	1	8	12	95	0
475	DIP	DIXA SP	1	8	12	95	4
476	DIP	DIXELLA SP	1	8	12	95	5
477	DIP	EMPIDIDAE	1	8	12	95	8

----------------------- STATION IDENTIFICATION=MZ9 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
478	DIP	EPHYDRIDAE	1	8	12	95	1
479	DIP	EUPARYPHUS SP	1	8	12	95	11
480	DIP	HEMERODROMIA SP	1	8	12	95	24
481	DIP	LIMNOPHORA SP	1	8	12	95	6
482	DIP	PERICOMA SP	1	8	12	95	1
483	DIP	SIMULIUM SP	1	8	12	95	2781
484	DIP	TIPULA SP	1	8	12	95	3
485	EPH	BAETIS SP	1	8	12	95	3328
486	GAS	GYRAULUS SP	1	8	12	95	0
487	GAS	LYMNAEIDAE	1	8	12	95	1
488	GAS	PHYSELLA SP	1	8	12	95	29
489	HYD	HYDRACARINA	1	8	12	95	562
490	NEM	NEMATA	1	8	12	95	0
491	NPH	NEMATOMORPHA	1	8	12	95	1
492	ODO	ARGIA SP	1	8	12	95	2
493	OLI	OLIGOCHAETA	1	8	12	95	55
494	PEL	PISIDIUM SP	1	8	12	95	5
495	PEL	SPHAERIIDAE	1	8	12	95	0
496	PEL	SPHAERIUM SP	1	8	12	95	0
497	PEL	SPHAERIUM?	1	8	12	95	5
498	TRI	HESPEROPHYLAX SP	1	8	12	95	6
499	TRI	HYDROPSYCHE SP	1	8	12	95	60
500	TRI	HYDROPTILA SP	1	8	12	95	566
501	TRI	OCHROTRICHIA SP	1	8	12	95	81
502	AMP	HYALELLA AZTECA	2	8	12	95	9
503	CHI	CHIRONOMIDAE	2	8	12	95	84
504	CHI	CHIRONOMINI	2	8	12	95	5
505	CHI	ORTHOCLADIINAE	2	8	12	95	1944
506	CHI	TANYPODINAE	2	8	12	95	280
507	CHI	TANYTARSINI	2	8	12	95	479
508	COL	AGABINUS SP	2	8	12	95	1
509	COL	AGABUS SP	2	8	12	95	0
510	COL	HALIPLUS SP	2	8	12	95	3
511	COL	HELICHUS SP	2	8	12	95	1
512	COL	HELOPHORUS SP	2	8	12	95	0
513	COL	HYGROTUS/HYDROPOR	2	8	12	95	0
514	COL	MICROCYLLOEPUS PUSILLUS	2	8	12	95	1
515	COL	OPTIOSERVUS SP	2	8	12	95	35
516	DIP	CERATOPOGONIDAE	2	8	12	95	13
517	DIP	CERATOPOGONIDAE?	2	8	12	95	0
518	DIP	CHELIFERA SP	2	8	12	95	10
519	DIP	CULEX SP	2	8	12	95	0
520	DIP	DIXA SP	2	8	12	95	3
521	DIP	DIXELLA SP	2	8	12	95	0
522	DIP	EMPIDIDAE	2	8	12	95	3
523	DIP	EPHYDRIDAE	2	8	12	95	0
524	DIP	EUPARYPHUS SP	2	8	12	95	13
525	DIP	HEMERODROMIA SP	2	8	12	95	14
526	DIP	LIMNOPHORA SP	2	8	12	95	8
527	DIP	PERICOMA SP	2	8	12	95	0

----------------------- STATION IDENTIFICATION=MZ9 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
528	DIP	SIMULIUM SP	2	8	12	95	1663
529	DIP	TIPULA SP	2	8	12	95	7
530	EPH	BAETIS SP	2	8	12	95	2525
531	GAS	GYRAULUS SP	2	8	12	95	1
532	GAS	LYMNAEIDAE	2	8	12	95	5
533	GAS	PHYSELLA SP	2	8	12	95	13
534	HYD	HYDRACARINA	2	8	12	95	441
535	NEM	NEMATA	2	8	12	95	2
536	NPH	NEMATOMORPHA	2	8	12	95	0
537	ODO	ARGIA SP	2	8	12	95	0
538	OLI	OLIGOCHAETA	2	8	12	95	99
539	PEL	PISIDIUM SP	2	8	12	95	1
540	PEL	SPHAERIIDAE	2	8	12	95	2
541	PEL	SPHAERIUM SP	2	8	12	95	3
542	PEL	SPHAERIUM?	2	8	12	95	0
543	TRI	HESPEROPHYLAX SP	2	8	12	95	4
544	TRI	HYDROPSYCHE SP	2	8	12	95	61
545	TRI	HYDROPTILA SP	2	8	12	95	511
546	TRI	OCHROTRICHIA SP	2	8	12	95	45
547	AMP	HYALELLA AZTECA	3	8	12	95	22
548	CHI	CHIRONOMIDAE	3	8	12	95	47
549	CHI	CHIRONOMINI	3	8	12	95	1
550	CHI	ORTHOCLADIINAE	3	8	12	95	898
551	CHI	TANYPODINAE	3	8	12	95	428
552	CHI	TANYTARSINI	3	8	12	95	812
553	COL	AGABINUS SP	3	8	12	95	4
554	COL	AGABUS SP	3	8	12	95	0
555	COL	HALIPLUS SP	3	8	12	95	2
556	COL	HELICHUS SP	3	8	12	95	1
557	COL	HELOPHORUS SP	3	8	12	95	2
558	COL	HYGROTUS/HYDROPOR	3	8	12	95	0
559	COL	MICROCYLLOEPUS PUSILLUS	3	8	12	95	2
560	COL	OPTIOSERVUS SP	3	8	12	95	95
561	DIP	CERATOPOGONIDAE	3	8	12	95	24
562	DIP	CERATOPOGONIDAE?	3	8	12	95	0
563	DIP	CHELIFERA SP	3	8	12	95	4
564	DIP	CULEX SP	3	8	12	95	1
565	DIP	DIXA SP	3	8	12	95	0
566	DIP	DIXELLA SP	3	8	12	95	0
567	DIP	EMPIDIDAE	3	8	12	95	1
568	DIP	EPHYDRIDAE	3	8	12	95	0
569	DIP	EUPARYPHUS SP	3	8	12	95	11
570	DIP	HEMERODROMIA SP	3	8	12	95	12
571	DIP	LIMNOPHORA SP	3	8	12	95	7
572	DIP	PERICOMA SP	3	8	12	95	0
573	DIP	SIMULIUM SP	3	8	12	95	1102
574	DIP	TIPULA SP	3	8	12	95	1
575	EPH	BAETIS SP	3	8	12	95	2049
576	GAS	GYRAULUS SP	3	8	12	95	1
577	GAS	LYMNAEIDAE	3	8	12	95	6

----------------------- STATION IDENTIFICATION=MZ9 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
578	GAS	PHYSELLA SP	3	8	12	95	37
579	HYD	HYDRACARINA	3	8	12	95	271
580	NEM	NEMATA	3	8	12	95	4
581	NPH	NEMATOMORPHA	3	8	12	95	0
582	ODO	ARGIA SP	3	8	12	95	4
583	OLI	OLIGOCHAETA	3	8	12	95	75
584	PEL	PISIDIUM SP	3	8	12	95	22
585	PEL	SPHAERIIDAE	3	8	12	95	7
586	PEL	SPHAERIUM SP	3	8	12	95	0
587	PEL	SPHAERIUM?	3	8	12	95	16
588	TRI	HESPEROPHYLAX SP	3	8	12	95	8
589	TRI	HYDROPSYCHE SP	3	8	12	95	36
590	TRI	HYDROPTILA SP	3	8	12	95	400
591	TRI	OCHROTRICHIA SP	3	8	12	95	29

----------------------- STATION IDENTIFICATION=MZG -----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
592	AMP	HYALELLA AZTECA	1	8	12	95	2
593	CHI	CHIRONOMIDAE	1	8	12	95	1
594	CHI	CHIRONOMINI	1	8	12	95	0
595	CHI	ORTHOCLADIINAE	1	8	12	95	170
596	CHI	PRODIAMESINAE	1	8	12	95	0
597	CHI	TANYPODINAE	1	8	12	95	18
598	CHI	TANYTARSINI	1	8	12	95	1
599	COL	AGABINUS SP	1	8	12	95	8
600	COL	HYDROPORUS SP	1	8	12	95	0
601	COL	OPTIOSERVUS SP	1	8	12	95	346
602	DIP	CERATOPOGONIDAE	1	8	12	95	5
603	DIP	CHELIFERA SP	1	8	12	95	9
604	DIP	DIXA SP	1	8	12	95	1
605	DIP	PSEUDOLIMNOPHILA SP	1	8	12	95	1
606	DIP	SIMULIIDAE	1	8	12	95	0
607	DIP	SIMULIUM SP	1	8	12	95	166
608	DIP	TIPULA SP	1	8	12	95	1
609	EPH	AMELETUS SP	1	8	12	95	0
610	EPH	BAETIS SP	1	8	12	95	550
611	EPH	HEPTAGENIIDAE	1	8	12	95	0
612	EPH	NIXE SP	1	8	12	95	1
613	GAS	PHYSELLA SP	1	8	12	95	2
614	HYD	HYDRACARINA	1	8	12	95	11
615	NEM	NEMATA	1	8	12	95	15
616	OLI	OLIGOCHAETA	1	8	12	95	69
617	PEL	PISIDIUM SP	1	8	12	95	0
618	PEL	SPHAERIUM SP	1	8	12	95	1
619	PLA	PLANARIIDAE	1	8	12	95	0
620	PLE	SWELTSA SP	1	8	12	95	1
621	TRI	HYDROPSYCHE SP	1	8	12	95	44

----------------------- STATION IDENTIFICATION=MZG -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
622	TRI	HYDROPTILA SP	1	8	12	95	0
623	TRI	LIMNEPHILIDAE	1	8	12	95	0
624	TRI	LIMNEPHILUS SP	1	8	12	95	1
625	TRI	OCHROTRICHIA SP	1	8	12	95	7
626	AMP	HYALELLA AZTECA	2	8	12	95	0
627	CHI	CHIRONOMIDAE	2	8	12	95	0
628	CHI	CHIRONOMINI	2	8	12	95	1
629	CHI	ORTHOCLADIINAE	2	8	12	95	30
630	CHI	PRODIAMESINAE	2	8	12	95	0
631	CHI	TANYPODINAE	2	8	12	95	10
632	CHI	TANYTARSINI	2	8	12	95	0
633	COL	AGABINUS SP	2	8	12	95	2
634	COL	HYDROPORUS SP	2	8	12	95	0
635	COL	OPTIOSERVUS SP	2	8	12	95	125
636	DIP	CERATOPOGONIDAE	2	8	12	95	5
637	DIP	CHELIFERA SP	2	8	12	95	4
638	DIP	DIXA SP	2	8	12	95	2
639	DIP	PSEUDOLIMNOPHILA SP	2	8	12	95	0
640	DIP	SIMULIIDAE	2	8	12	95	1
641	DIP	SIMULIUM SP	2	8	12	95	43
642	DIP	TIPULA SP	2	8	12	95	0
643	EPH	AMELETUS SP	2	8	12	95	0
644	EPH	BAETIS SP	2	8	12	95	292
645	EPH	HEPTAGENIIDAE	2	8	12	95	0
646	EPH	NIXE SP	2	8	12	95	4
647	GAS	PHYSELLA SP	2	8	12	95	1
648	HYD	HYDRACARINA	2	8	12	95	1
649	NEM	NEMATA	2	8	12	95	11
650	OLI	OLIGOCHAETA	2	8	12	95	14
651	PEL	PISIDIUM SP	2	8	12	95	0
652	PEL	SPHAERIUM SP	2	8	12	95	0
653	PLA	PLANARIIDAE	2	8	12	95	0
654	PLE	SWELTSA SP	2	8	12	95	0
655	TRI	HYDROPSYCHE SP	2	8	12	95	0
656	TRI	HYDROPTILA SP	2	8	12	95	0
657	TRI	LIMNEPHILIDAE	2	8	12	95	0
658	TRI	LIMNEPHILUS SP	2	8	12	95	0
659	TRI	OCHROTRICHIA SP	2	8	12	95	1
660	AMP	HYALELLA AZTECA	3	8	12	95	2
661	CHI	CHIRONOMIDAE	3	8	12	95	4
662	CHI	CHIRONOMINI	3	8	12	95	6
663	CHI	ORTHOCLADIINAE	3	8	12	95	72
664	CHI	PRODIAMESINAE	3	8	12	95	1
665	CHI	TANYPODINAE	3	8	12	95	41
666	CHI	TANYTARSINI	3	8	12	95	64
667	COL	AGABINUS SP	3	8	12	95	5
668	COL	HYDROPORUS SP	3	8	12	95	1
669	COL	OPTIOSERVUS SP	3	8	12	95	193
670	DIP	CERATOPOGONIDAE	3	8	12	95	13
671	DIP	CHELIFERA SP	3	8	12	95	2

---------------------- STATION IDENTIFICATION=MZG ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
672	DIP	DIXA SP	3	8	12	95	1
673	DIP	PSEUDOLIMNOPHILA SP	3	8	12	95	0
674	DIP	SIMULIIDAE	3	8	12	95	0
675	DIP	SIMULIUM SP	3	8	12	95	21
676	DIP	TIPULA SP	3	8	12	95	0
677	EPH	AMELETUS SP	3	8	12	95	1
678	EPH	BAETIS SP	3	8	12	95	179
679	EPH	HEPTAGENIIDAE	3	8	12	95	1
680	EPH	NIXE SP	3	8	12	95	2
681	GAS	PHYSELLA SP	3	8	12	95	4
682	HYD	HYDRACARINA	3	8	12	95	3
683	NEM	NEMATA	3	8	12	95	38
684	OLI	OLIGOCHAETA	3	8	12	95	141
685	PEL	PISIDIUM SP	3	8	12	95	1
686	PEL	SPHAERIUM SP	3	8	12	95	3
687	PLA	PLANARIIDAE	3	8	12	95	1
688	PLE	SWELTSA SP	3	8	12	95	1
689	TRI	HYDROPSYCHE SP	3	8	12	95	4
690	TRI	HYDROPTILA SP	3	8	12	95	3
691	TRI	LIMNEPHILIDAE	3	8	12	95	1
692	TRI	LIMNEPHILUS SP	3	8	12	95	4
693	TRI	OCHROTRICHIA SP	3	8	12	95	2

---------------------- STATION IDENTIFICATION=VD1 ----------------------

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
694	AMP	HYALELLA AZTECA	1	8	12	95	0
695	CHI	CHIRONOMIDAE	1	8	12	95	8
696	CHI	CHIRONOMINI	1	8	12	95	12
697	CHI	ORTHOCLADIINAE	1	8	12	95	402
698	CHI	TANYPODINAE	1	8	12	95	34
699	CHI	TANYTARSINI	1	8	12	95	26
700	COL	AGABINUS SP	1	8	12	95	1
701	COL	HELICHUS SP	1	8	12	95	0
702	COL	NEBRIOPORUS/STICT	1	8	12	95	0
703	COL	OPTIOSERVUS SP	1	8	12	95	8
704	COL	OREODYTES SP	1	8	12	95	1
705	DIP	CERATOPOGONIDAE	1	8	12	95	13
706	DIP	CHELIFERA SP	1	8	12	95	5
707	DIP	EPHYDRIDAE	1	8	12	95	0
708	DIP	HEMERODROMIA SP	1	8	12	95	1
709	DIP	SIMULIUM SP	1	8	12	95	57
710	DIP	TABANUS SP	1	8	12	95	1
711	DIP	TIPULIDAE	1	8	12	95	0
712	EPH	BAETIS SP	1	8	12	95	526
713	EPH	CALLIBAETIS SP	1	8	12	95	0
714	EPH	CENTROPTILUM SP	1	8	12	95	1
715	EPH	NIXE SP	1	8	12	95	9

---------------------- STATION IDENTIFICATION=VD1 ----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
716	EPH	PARALEPTOPHLEBIA SP	1	8	12	95	1
717	GAS	PHYSELLA SP	1	8	12	95	2
718	HYD	HYDRACARINA	1	8	12	95	32
719	NEM	NEMATA	1	8	12	95	10
720	ODO	ARGIA SP	1	8	12	95	2
721	OLI	OLIGOCHAETA	1	8	12	95	26
722	PLE	CAPNIIDAE	1	8	12	95	1
723	PLE	ISOGENOIDES SP	1	8	12	95	0
724	PLE	SWELTSA SP	1	8	12	95	2
725	PLE	ZAPADA SP	1	8	12	95	0
726	TRI	HESPEROPHYLAX SP	1	8	12	95	2
727	TRI	HYDROPSYCHE SP	1	8	12	95	166
728	TRI	HYDROPSYCHIDAE	1	8	12	95	1
729	TRI	HYDROPTILA SP	1	8	12	95	82
730	TRI	HYDROPTILA?	1	8	12	95	0
731	TRI	HYDROPTILIDAE	1	8	12	95	1
732	TRI	OCHROTRICHIA SP	1	8	12	95	4
733	AMP	HYALELLA AZTECA	2	8	12	95	0
734	CHI	CHIRONOMIDAE	2	8	12	95	9
735	CHI	CHIRONOMINI	2	8	12	95	9
736	CHI	ORTHOCLADIINAE	2	8	12	95	163
737	CHI	TANYPODINAE	2	8	12	95	38
738	CHI	TANYTARSINI	2	8	12	95	13
739	COL	AGABINUS SP	2	8	12	95	0
740	COL	HELICHUS SP	2	8	12	95	1
741	COL	NEBRIOPORUS/STICT	2	8	12	95	0
742	COL	OPTIOSERVUS SP	2	8	12	95	3
743	COL	OREODYTES SP	2	8	12	95	0
744	DIP	CERATOPOGONIDAE	2	8	12	95	8
745	DIP	CHELIFERA SP	2	8	12	95	4
746	DIP	EPHYDRIDAE	2	8	12	95	1
747	DIP	HEMERODROMIA SP	2	8	12	95	3
748	DIP	SIMULIUM SP	2	8	12	95	40
749	DIP	TABANUS SP	2	8	12	95	0
750	DIP	TIPULIDAE	2	8	12	95	0
751	EPH	BAETIS SP	2	8	12	95	517
752	EPH	CALLIBAETIS SP	2	8	12	95	0
753	EPH	CENTROPTILUM SP	2	8	12	95	0
754	EPH	NIXE SP	2	8	12	95	7
755	EPH	PARALEPTOPHLEBIA SP	2	8	12	95	2
756	GAS	PHYSELLA SP	2	8	12	95	5
757	HYD	HYDRACARINA	2	8	12	95	9
758	NEM	NEMATA	2	8	12	95	1
759	ODO	ARGIA SP	2	8	12	95	8
760	OLI	OLIGOCHAETA	2	8	12	95	55
761	PLE	CAPNIIDAE	2	8	12	95	1
762	PLE	ISOGENOIDES SP	2	8	12	95	4
763	PLE	SWELTSA SP	2	8	12	95	0
764	PLE	ZAPADA SP	2	8	12	95	1
765	TRI	HESPEROPHYLAX SP	2	8	12	95	0

----------------------- STATION IDENTIFICATION=VD1 -----------------------
(continued)

OBS	ORDER	TAXON	SAMPNO	MONTH	DAY	YEAR	NUM
766	TRI	HYDROPSYCHE SP	2	8	12	95	49
767	TRI	HYDROPSYCHIDAE	2	8	12	95	0
768	TRI	HYDROPTILA SP	2	8	12	95	75
769	TRI	HYDROPTILA?	2	8	12	95	2
770	TRI	HYDROPTILIDAE	2	8	12	95	0
771	TRI	OCHROTRICHIA SP	2	8	12	95	3
772	AMP	HYALELLA AZTECA	3	8	12	95	1
773	CHI	CHIRONOMIDAE	3	8	12	95	7
774	CHI	CHIRONOMINI	3	8	12	95	7
775	CHI	ORTHOCLADIINAE	3	8	12	95	75
776	CHI	TANYPODINAE	3	8	12	95	45
777	CHI	TANYTARSINI	3	8	12	95	36
778	COL	AGABINUS SP	3	8	12	95	0
779	COL	HELICHUS SP	3	8	12	95	1
780	COL	NEBRIOPORUS/STICT	3	8	12	95	1
781	COL	OPTIOSERVUS SP	3	8	12	95	3
782	COL	OREODYTES SP	3	8	12	95	0
783	DIP	CERATOPOGONIDAE	3	8	12	95	8
784	DIP	CHELIFERA SP	3	8	12	95	1
785	DIP	EPHYDRIDAE	3	8	12	95	0
786	DIP	HEMERODROMIA SP	3	8	12	95	4
787	DIP	SIMULIUM SP	3	8	12	95	23
788	DIP	TABANUS SP	3	8	12	95	0
789	DIP	TIPULIDAE	3	8	12	95	1
790	EPH	BAETIS SP	3	8	12	95	288
791	EPH	CALLIBAETIS SP	3	8	12	95	1
792	EPH	CENTROPTILUM SP	3	8	12	95	0
793	EPH	NIXE SP	3	8	12	95	6
794	EPH	PARALEPTOPHLEBIA SP	3	8	12	95	4
795	GAS	PHYSELLA SP	3	8	12	95	6
796	HYD	HYDRACARINA	3	8	12	95	21
797	NEM	NEMATA	3	8	12	95	7
798	ODO	ARGIA SP	3	8	12	95	2
799	OLI	OLIGOCHAETA	3	8	12	95	26
800	PLE	CAPNIIDAE	3	8	12	95	0
801	PLE	ISOGENOIDES SP	3	8	12	95	0
802	PLE	SWELTSA SP	3	8	12	95	2
803	PLE	ZAPADA SP	3	8	12	95	0
804	TRI	HESPEROPHYLAX SP	3	8	12	95	0
805	TRI	HYDROPSYCHE SP	3	8	12	95	33
806	TRI	HYDROPSYCHIDAE	3	8	12	95	0
807	TRI	HYDROPTILA SP	3	8	12	95	35
808	TRI	HYDROPTILA?	3	8	12	95	0
809	TRI	HYDROPTILIDAE	3	8	12	95	0
810	TRI	OCHROTRICHIA SP	3	8	12	95	0

Appendix E

RAW QUALITATIVE BENTHIC MACROINVERTEBRATE DATA FOR BEAVER POND AT MZ-5 AND STOCK POND

MONTEZUMA CREEK AT MZ-5 BEAVER POND AND STOCK POND
AUGUST 1995 20:01 Thursday, May 30, 1996

----------------------- STATION IDENTIFICATION=MZ5 -----------------------

OBS	ORDER	TAXON	MONTH	DAY	YEAR
1	AMP	HYALLELA AZTECA	8	14	95
2	CHI	CHIRONOMIDAE	8	14	95
3	CHI	CHIRONOMINI	8	14	95
4	CHI	ORTHOCLADIINAE	8	14	95
5	CHI	TANYPODINAE	8	14	95
6	CHI	TANYTARSINI	8	14	95
7	COL	AGABETES SP	8	14	95
8	COL	AGABINUS SP	8	14	95
9	COL	AGABUS SP	8	14	95
10	COL	BEROSUS SP	8	14	95
11	COL	DYTISCIDAE	8	14	95
12	COL	HALIPLUS SP	8	14	95
13	COL	HELOPHORUS SP	8	14	95
14	COL	HYGROTUS SP	8	14	95
15	COL	LACCOPHILUS SP	8	14	95
16	COL	NEBRIOPORUS/STICT	8	14	95
17	COL	OREODYTES SP	8	14	95
18	COL	PARACYMUS SP	8	14	95
19	COL	RHANTUS SP	8	14	95
20	COL	TROPISTERNUS SP	8	14	95
21	DIP	CERATOPOGONIDAE	8	14	95
22	DIP	CHAOBORUS SP	8	14	95
23	DIP	CULEX SP	8	14	95
24	DIP	CULISETA SP	8	14	95
25	DIP	CYCLORRHAPHOUS	8	14	95
26	DIP	EPHYDRIDAE	8	14	95
27	DIP	SIMULIUM SP	8	14	95
28	DIP	TIPULA SP	8	14	95
29	EPH	BAETIS SP	8	14	95
30	EPH	CALLIBAETIS SP	8	14	95
31	GAS	LYMNAEIDAE	8	14	95
32	GAS	PHYSELLA SP	8	14	95
33	HEM	COENOCORIXA BIFIDA	8	14	95
34	HEM	COENOCORIXA UTAHENSIS	8	14	95
35	HEM	CORIXIDAE	8	14	95
36	HEM	GERRIS SP	8	14	95
37	HEM	HESPEROCORIXA LAEVIGATA	8	14	95
38	HEM	NOTONECTA SP	8	14	95
39	HEM	NOTONECTIDAE	8	14	95
40	HYD	HYDRACARINA	8	14	95
41	NEM	NEMATA	8	14	95
42	ODO	AESHNA SP	8	14	95
43	ODO	COENAGRION/ENALLA	8	14	95
44	ODO	COENAGRIONIDAE	8	14	95
45	ODO	ISCHNURA SP	8	14	95
46	ODO	LESTES SP	8	14	95
47	OLI	OLIGOCHAETA	8	14	95
48	PEL	PISIDIUM SP	8	14	95
49	PEL	SPHAERIIDAE	8	14	95
50	TRI	HYDROPTILA SP	8	14	95

----------------------- STATION IDENTIFICATION=STOCKP -----------------------

OBS	ORDER	TAXON	MONTH	DAY	YEAR
51	AMP	HYALLELA AZTECA	8	15	95
52	CHI	CHIRONOMIDAE	8	15	95
53	CHI	CHIRONOMINI	8	15	95
54	CHI	ORTHOCLADIINAE	8	15	95
55	CHI	PRODIAMESINAE	8	15	95
56	CHI	TANYPODINAE	8	15	95
57	CHI	TANYTARSINI	8	15	95
58	COL	AGABETES SP	8	15	95
59	COL	AGABINUS SP	8	15	95
60	COL	BEROSUS SP	8	15	95
61	COL	CYMBIODYTA SP	8	15	95
62	COL	HALIPLUS DORSOMACULA	8	15	95
63	COL	HELOPHORUS SP	8	15	95
64	COL	HYDROPORUS SP	8	15	95
65	COL	HYGROTUS SP	8	15	95
66	COL	LACCOPHILUS SP	8	15	95
67	COL	LIODESSUS?	8	15	95
68	COL	NEBRIOPORUS/STICT	8	15	95
69	COL	OREODYTES SP	8	15	95
70	DIP	CERATOPOGONIDAE	8	15	95
71	DIP	CULEX SP	8	15	95
72	DIP	EPHYDRIDAE	8	15	95
73	EPH	CALLIBAETIS SP	8	15	95
74	GAS	PHYSELLA SP	8	15	95
75	HEM	COENOCORIXA LAEVIGATA	8	15	95
76	HEM	COENOCORIXA UTAHENSIS	8	15	95
77	HEM	CORISELLA INSCRIPTA	8	15	95
78	HEM	CORISELLA TARSALIS	8	15	95
79	HEM	HESPEROCORIXA LAEVITATA	8	15	95
80	HEM	NOTONECTA SP	8	15	95
81	HIR	HELOBDELLA STAGNALIS	8	15	95
82	NEM	NEMATA	8	15	95
83	ODO	AESHNA SP	8	15	95
84	ODO	MICRATHYRIA SP	8	15	95
85	OLI	OLIGOCHAETA	8	15	95
86	PEL	PISIDIUM SP	8	15	95